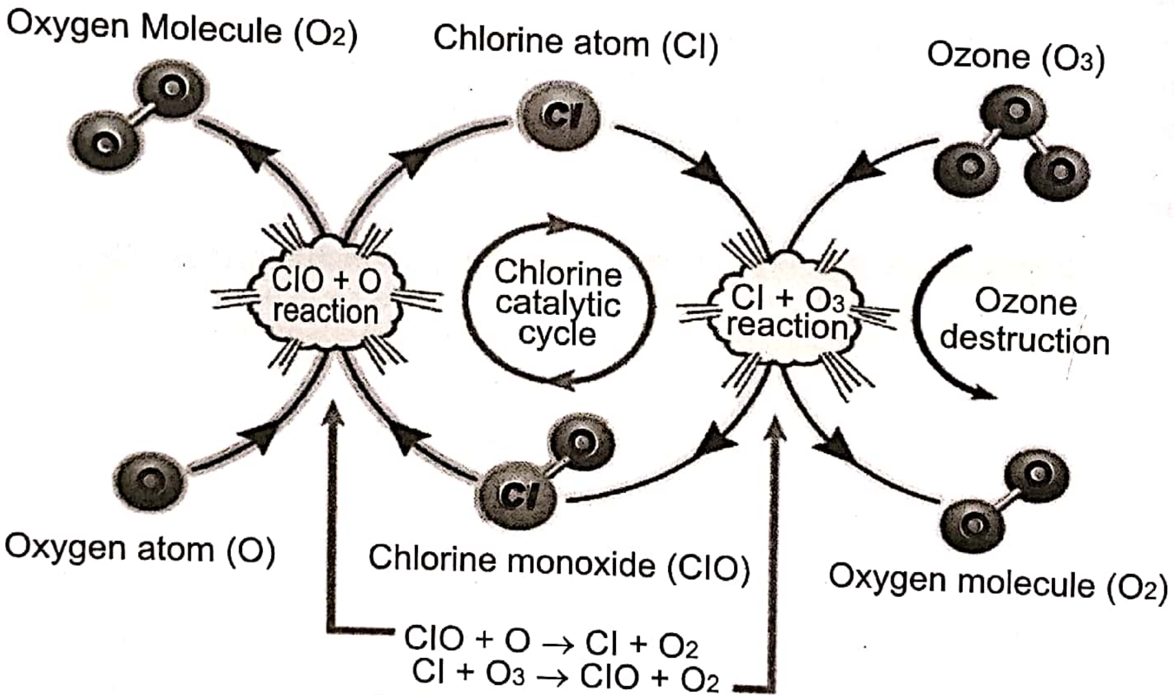
Exposure to higher amounts of UV radiation could have serious impacts on human beings, animals and plants, such as the following:

- Weakening of the human immune system (immune-suppression).
- UV rays can damage DNA & can cause mutation.
- Several of the world's major crop species are particularly vulnerable to increased UV radiations, resulting in reduced growth, photosynthesis and flowering. These species include wheat, rice, barley, oats, corn, soybeans, peas, tomatoes, cucumbers, cauliflower, broccoli and carrots.
- In particular, plankton (tiny organisms in the surface layer of oceans) is threatened by increased UV radiation. Plankton is the first vital step in aquatic food chains.
- Decreases in plankton could disrupt the fresh and salt-water food chains, and lead to a species shift in waters.
- Loss of biodiversity in our oceans, rivers and lakes could reduce fish yields for commercial and sport fisheries.

Ozone Depletion

In the 1970s, scientists became concerned when they discovered that chemicals called chlorofluorocarbons, or CFCs, posed a possible threat to the ozone layer. These chlorine-containing chemicals rise into the upper stratosphere and are broken down by sunlight, whereupon the chlorine reacts with and destroys ozone molecules. About 100,000 molecules of ozone are broken down per CFC molecule. The so-called ozone "hole," is a thinned region of the ozone layer that develops in the Antarctic spring and continues for several months before thickening again.



$$ClO + O \rightarrow Cl + O_2$$
$$Cl + O_3 \rightarrow ClO + O_2$$
$$\text{Net: } O + O_3 \rightarrow 2O_2$$

Figure: Ozone Depletion Process

Ozone Depleting Substances (ODS)

Stratospheric ozone is being destroyed by a group of manufactured chemicals, containing chlorine and/or bromine. These chemicals are called "ozone-depleting substances, (ODS). Few of them are listed below.

- **CFCs and HCFCs** — mostly used in refrigeration, air-conditioning and heat pump systems. Only HCFCs can continue to be used for a limited period of time.
- **Halons** — used historically as fire suppression agents and fire fighting, but now only allowed in very limited situations.
- **Carbon tetrachloride (Tetra chloromethane)** — limited solvent use in laboratories and chemical and pharmaceutical industry.
- **1,1,1,-trichloroethane** — limited solvent use in laboratories and chemical and pharmaceutical industry.
- **Methyl bromide** — historically used in fumigation, soil treatment, pest control, quarantine and market gardening.
- **Hydrobromofluorocarbons** — historically used in fire suppression systems and fire fighting.
- **Bromochloromethane** — historically used in the manufacture of biocides.

How to Control Ozone Depletion

Growing concern for ozone depletion led to the adoption of the Montreal Protocol in 1987, in order to reduce and control industrial emission of chlorofluorocarbons (CFCs). We too can do our bit to save the ozone. Use/buy more recycled products, save energy, take public transport, and, most importantly, spread awareness. Our individual efforts can go a long way in saving the ozone layer.

MONTREAL PROTOCOL

The Montreal Protocol on substances that deplete the ozone layer (a protocol to the Vienna Convention for the protection of the ozone layer) is an international treaty designed to protect the ozone layer by phasing out the production of numerous substances that are responsible for ozone depletion. The Montreal Protocol was agreed on September 16, 1987 and entered into force on January 1, 1989. Because of the risks posed by ozone depletion, leaders from many countries decided to craft a workable solution. Since 1987, 191 nations have ratified the landmark environmental treaty.

The Protocol's chief aim is to reduce and eventually eliminate the production and use of man-made ozone depleting substances (ODS). By agreeing to the terms of the Montreal Protocol, signatory nations — including the United States — committed to take actions to protect the ozone layer, hoping in the long-term to reverse the damage that had been done by the use of ozone depleting substances. If the Montreal Protocol is followed in entirety with full spirit, the overall quantity of ozone layer depletion causing gases mainly chlorine and bromine is bound to reduce in the atmosphere.

As a result of the international agreement, the ozone hole in Antarctica is slowly recovering. Climate projections indicate that the ozone layer will return to 1980 levels between 2050 and 2070. Due to its widespread adoption and implementation it has been hailed as an example of exceptional international co-operation, with Kofi Annan the then secretary general of UN quoted as saying that "perhaps the single most successful international agreement to date has been the Montreal Protocol".

ACID RAIN

"Acid rain" is a broad term referring to a mixture of wet and dry deposition (deposited material) from the atmosphere containing higher than normal amounts of nitric and sulfuric acids. Sulphur dioxide and nitrogen oxides react with water and other chemicals in the air to form sulphuric acid, sulphurous acid, nitrous acid and other pollutants. The chemical reactions of these pollutants are discussed below:

$$SO_2+H_2O \rightarrow H_2SO_3 \text{ (sulphorous acid)}$$

$$2NO_2+H_2O \rightarrow HNO_2 \text{ (nitrous acid)}+HNO_3 \text{ (nitric acid)}$$

These acid pollutants reach high into the atmosphere, travel with the wind for hundreds of miles and eventually return to the ground by way of rain, snow or fog.

Wet Deposition: If the acid chemicals in the air are blown into areas where the weather is wet, the acids can fall to the ground in the form of rain, snow, fog, or mist.

Dry Deposition: In areas where the weather is dry, the acid chemicals may become incorporated into dust or smoke and fall to the ground through dry deposition, sticking to the ground, buildings, homes, cars, and trees. About half of the acidity in the atmosphere falls back to earth through dry deposition.

Measurement of Acid Rain

Acid rain is measured using a scale called "pH scale." The lower a substance's pH, the more acidic it is. Pure water has a pH of 7.0. However, normal rain is slightly acidic because carbon dioxide (CO_2) dissolves into it forming weak carbonic acid, giving the resulting mixture a pH of approximately 5.6 at typical atmospheric concentrations of CO_2. Rain, snow or fog with a pH below 5.6 is considered acid rain.

Effects of Acid Rain

Following are the effects of acid rain:

1. In soil, acid rain dissolves and washes away nutrients needed by plants. By removing useful nutrients from the soil, acid rain slows the growth of plants, especially trees.
2. It can also dissolve toxic substances, such as aluminium and mercury, which are naturally present in some soils, freeing these toxins to pollute water or to poison plants that absorb them.
3. It also attacks trees more directly by eating holes in the waxy coating of leaves and needles, causing brown dead spots on leaves.
4. Acid rain falls into drains streams, lakes and marshes. Hence, water bodies become acidic and unfit for life.
5. The effects of acid rain on wildlife can be far-reaching. If population of plant animal is adversely affected by acid rain, animals that feed on that plant or animal may also suffer. Ultimately, an entire ecosystem may be endangered.
6. Acid rain and the dry deposition of acidic particles contribute to the corrosion of metals (such as bronze) and the deterioration of paint and stone (such as marble and limestone). These effects significantly reduce the societal value of buildings, bridges, cultural objects (such as statues, monuments, and tombstones), and cars.
7. In the air, acids join with other chemicals to produce urban **smog,** which can irritate the lungs and make breathing difficult, especially for people who already have asthma,

bronchitis or other respiratory diseases. Solid particles of sulphates, a class of minerals derived from sulphur dioxide, are thought to be especially damaging to the lungs.

8. Smog in the atmosphere from sulphur dioxide (SO_2) and nitrogen oxides (NOx) emissions contribute to visibility impairment.

forts to Control Acid Rain

Acid rain can be controlled by adopting following measures:

- Acid rain can best be curtailed by reducing the amount of sulphur dioxide and nitrogen oxides released by power plants, motor vehicles and factories. The simplest way to cut these emissions is to use less energy from fossil fuels.
- Individuals can help. Every time a consumer buys an energy-efficient appliance, adds insulation to a house, or takes a bus to work, he or she conserves energy and, as a result, fights acid rain.
- Another way to cut emissions of sulphur dioxide and nitrogen oxides is by switching to cleaner-burning fuels. For instance, coal can be high or low in sulphur, and some coal contains sulphur in a form that can be washed out easily before burning. By using more of the low-sulphur or cleanable types of coal, electric utility companies and other industries can pollute less.
- Use renewable energy sources.
- Using devices called scrubbers to chemically remove the SO_2 from the gases leaving the smokestack and recycling to use as a raw material.
- Similar to scrubbers on power plants, catalytic converters reduce NOx emissions from cars.

CLIMATE CHANGE (MCQS)

te: Answers are Bold and Underlined:

Climate variations on the scale of hundreds of years may be caused by ______________:

(a) Solar radiation variation caused by orbital variations

(b) **Changes in ocean currents** (c) Volcanic eruptions

(d) Plate tectonic cycles (e) None of these

Carbon dioxide has been locked up over geological time as ______________:

(a) Part of the mantle (b) **Limestone and fossils**

(c) Material dissolved in the oceans (d) Material lost into space

Earth's early greenhouse climate resulted in a climate much like that of ________ today.

(a) Mercury (b) **Venus** (c) Mars (d) Jupiter

Which one refers to the oceans, seas, rivers, fresh water and underground water?

(a) Cryosphere (b) Atmosphere (c) Biosphere (d) **Hydrosphere**

Which of the following gases are included in the category 'greenhouse gases'?

(a) Methane (b) Nitrous oxide (c) Carbon dioxide (d) **All of these**

6. **Which type of energy transfer occurs between two substances in direct physical contact?**
(a) Radiation (b) Circulation (c) Conduction (d) Convection

7. **Which two gases make up 99% of Earth's atmosphere?**
(a) Argon and nitrogen (b) Nitrogen and oxygen
(c) Oxygen and carbon dioxide (d) Carbon dioxide and nitrogen

8. **Which is the most abundant greenhouse gas in Earth's atmosphere?**
(a) CO_2 (b) Nitrogen (c) Methane (d) Water vapour

9. **Which greenhouse gas is produced only through human activity and no natural sources?**
(a) Ozone (b) Nitrogen (c) Methane (d) Halocarbons

10. **Which is not an example of electromagnetic radiation?**
(a) X-rays (b) Albedo (c) Visible light (d) Radio waves

11. **Which type of energy transfer occurs as energy travels from the Sun to Earth?**
(a) Radiation (b) Circulation (c) Conduction (d) Convection

12. **Which is the largest single indicator of climate change?**
(a) Extinction (b) Deforestation (c) Global warming (d) Epidemics

13. **Which activity in developing countries may be a major contributor to global climate change?**
(a) Tourism (b) Agriculture (c) Electricity (d) Automobiles

14. **The greenhouse effect is caused by:**
(a) Greenhouse gases in the lower atmosphere absorbing solar radiation.
(b) Greenhouse gases in the lower atmosphere absorbing radiation from the Earth's surface, and preventing much of it escaping into space.
(c) Too much heat in the atmosphere. (d) Too much sunshine reaching Earth.

15. **What greenhouse gas was not present in the atmosphere in pre-industrial times?**
(a) Chlorofluorocarbon (b) Carbon dioxide
(c) Nitrous oxide (d) Methane

16. **Which of these countries has the highest per capita carbon dioxide emissions?**
(a) United States (b) Australia (c) Saudi Arabia (d) China

17. **Which of the following activities contributes the most to carbon emissions globally?**
(a) Agriculture (b) Transport
(c) Forestry (d) Energy supply

18. **When did Kyoto Protocol entered into force?**
(a) 1997 (b) 2000 (c) 2005 (d) 2012

19. **Which of the following is not a Kyoto Flexibility Mechanism?**
(a) Emissions Trading (b) Adaptation Mechanism
(c) Joint Implementation (d) Clean Development Mechanism

20. **This mechanism allows developed countries to mitigate their emissions through other developed countries.**

(a) Clean Development Mechanism (b) **Joint Implementation**
(c) Technology Mechanism (d) Emissions Trading

21. **Which mechanism allows countries to earn Certified Emission Reduction (CER) units?**
(a) **Emissions Trading** (b) Joint Implementation
(c) Clean Development Mechanism (d) Technology Mechanism

22. **Countries in which region have achieved maximum emission reductions compared to the 1990 levels.**
(a) **Europe** (b) North America (c) East Asia (d) South Asia

23. **Which gas was added to the list of GHG under the protocol in the second commitment period?**
(a) **Nitrogen trifluoride (NF_3)** (b) Water Wapor (H_2O)
(c) Carbon Monoxide (CO) (d) Methane (CH_4)

24. **The time gap between the adoption of Kyoto Protocol and its entry into force occured due to the following reason:**
(a) The document was not ratified by the US Congress.
(b) The document was not ready until 2005.
(c) **The document was not ratified by sufficient number of countries.**
(d) The document was not meant to enter into force before 2005.

25. **Which of the following was not achieved by Kyoto Protocol's first commitment period?**
(a) Establishment of Adaptation Fund.
(b) **Decrease in global emissions by 5% compared to 1990 levels.**
(c) Establishment of Technology Transfer Mechanisms.
(d) Success of CDM.

26. **The Montreal Protocol (1987) was established to deal with the depletion of:**
(a) Fish and wildlife stocks. (b) The global commons.
(c) Greenhouse gas emissions. (d) **The ozone layer.**

27. **Which key player pulled out of the Kyoto Protocol in 2011, thereby undermining its legitimacy?**
(a) **Canada** (b) China
(c) The United States (d) The European Union

28. **In its 2013 report, the IPCC projected the average increase in Global temperature about:**
(a) 1.6°F (0.9°C) (b) **2.7°F (1.5°C)** (c) 3.6°F (2°C) (d) 4.6°F (2.6°C)

29. **Is ozone good or bad for humans?**
(a) Neither – it is neutral (b) Good
(c) Bad (d) **Both (b) and (c)**

30. **Montreal protocol goal is to phase out.**
(a) Green House gases (b) **Ozone depleting substances**
(c) Water Pollutants (d) All of these

CHAPTER 5

GEOSPATIAL TECHNOLOGIES

Geospatial technology refers to equipment used in visualization, measurement, and analysis of earth's features, typically involving such systems as GPS (global positioning systems), GIS (geographical information systems), and RS (remote sensing). It is necessary to have the understanding of the electromagnetic radiations and satellites before going into details of geospatial technology. These topics are also part of the CSS syllabus.

ELECTROMAGNETIC RADIATION

Electromagnetic (EM) radiation is a form of energy that is all around us and takes many forms, such as light rays, radio waves, microwaves, X-rays and gamma rays. Visible light is only a small portion of the EM spectrum, which contains a broad range of electromagnetic wavelengths.

Properties of Electromagnetic Waves

Amplitude: Amplitude is a measure of how big the wave is. Imagine a wave in the ocean. It could be a little ripple or a giant tsunami. The amplitude of a wave is measured as:

1. the height from the equilibrium point to the highest point of a crest, or
2. the depth from the equilibrium point to the lowest point of a trough

Wavelength: Any of the parts of the wave that are pointing up like mountains are called crests. Any part that is sloping down like a valley is a trough. **Wavelength** is defined as the distance between two adjacent crests or troughs wavelength is denoted by λ (Lambda).

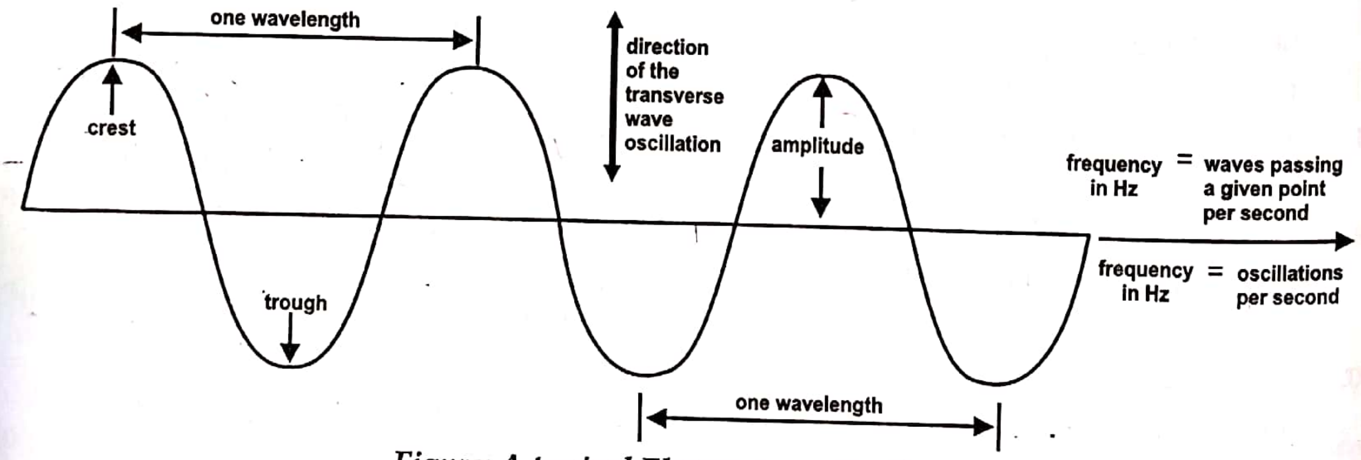

one wavelength
crest
direction of the transverse wave oscillation
amplitude
frequency in Hz = waves passing a given point per second
frequency in Hz = oscillations per second
trough
one wavelength

Figure: A typical Electromagnetic Wave

Frequency: The frequency of a wave is the number of waves produced by a source each second. The unit of frequency is the hertz (Hz). Frequency is denoted by f.

Frequency tells us how many waves are passing a point per second, the inverse of time. Wavelength tells us the length of those waves in metres, almost like a displacement. If we multiply these two together, we are really multiplying 1/s and m... which gives us m/s, the velocity of the wave!

$$V = f\lambda$$

Where:

v = velocity of the wave (m/s);

f = frequency (Hz); and

λ = wavelength (m)

The other properties of electromagnetic waves are:

1. The velocity of electromagnetic wave in vacuum is 3×10^8 m/s that is equal to speed of light.
2. The existence of medium is not essential for propagation of EM waves.
3. EM waves are transverse in nature.
4. EM waves have momentum.
5. There is no deflection on account of magnetic or electric field.
6. They can exhibit diffraction and interference.

Electromagnetic Spectrum

Electromagnetic waves can be characterized by either the frequency or wavelength of their oscillations to form the electromagnetic spectrum, which includes, in order of increasing frequency and decreasing wavelength: radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation, X-rays and gamma rays. This array of rays is called electromagnetic spectrum.

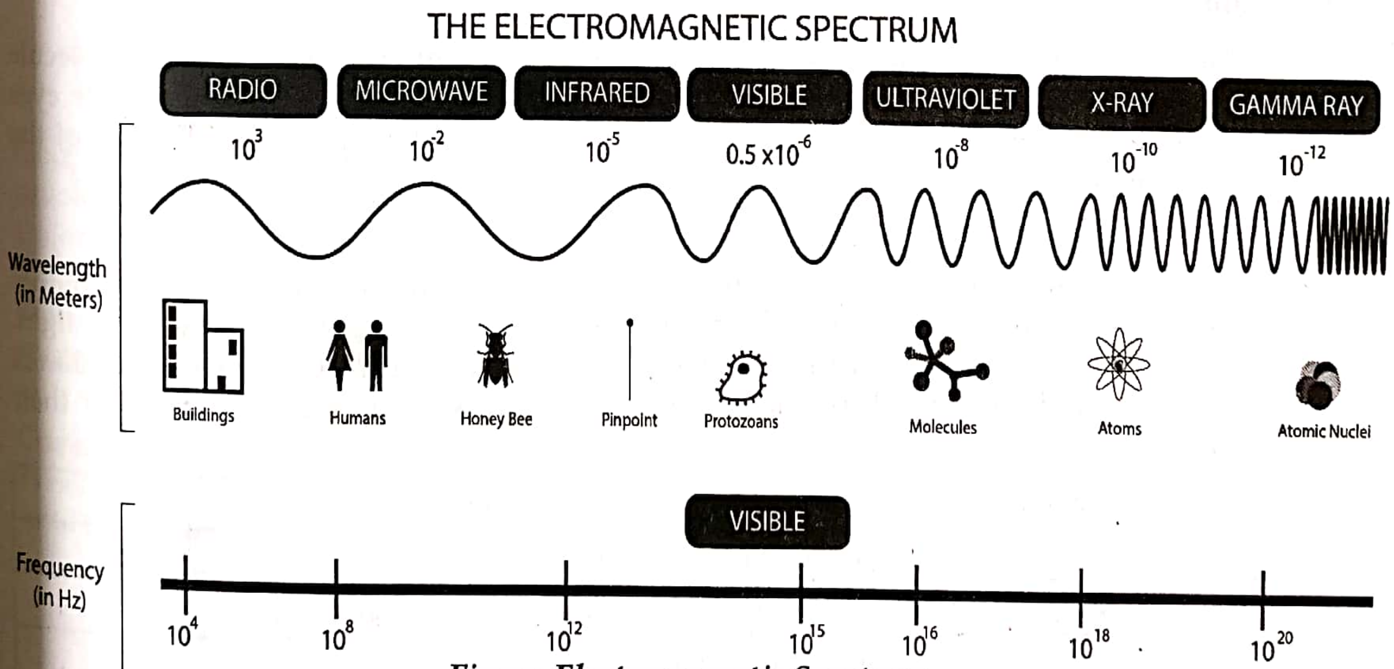


Figure: Electromagnetic Spectrum

Radio Waves

Radio waves are longer than 1 mm to several kilometres. Since these are the longest waves, they have the lowest energy and are associated with the lowest temperatures. Radio waves are found everywhere: in the background radiation of the universe, in interstellar clouds, and in the cool remnants of supernova explosions, to name a few. Radio waves do more than just bringing music to radio. They also carry signals for television and cellular phones. Radio waves are often used to transmit data and have been used for all sorts of applications including satellites, radar, and computer networks.

Microwaves

Microwaves are shorter than radio waves with wavelengths measured in centimetres. We use microwaves to cook food, transmit information, and in radar that helps to predict the weather. Microwaves are useful in communication because they can penetrate clouds, smoke, and light rain. The universe is filled with cosmic microwave background radiation that scientists believe are clues to the origin of the universe they call the Big Bang.

Infra-red

Infra-red wavelengths span from 710 nm to 1 millimetre (from the width of a pinpoint to the size of small plant seeds). At a temperature of 37° C, our bodies give off infra-red wavelengths with a peak intensity near 900 nm. Infra-red waves are sometimes classified as "near" infra-red and "far" infra-red. **Near infrared** waves are the waves that are closer to visible light in wavelength. **Far infra-red** waves are further away from visible light in wavelength.

Infra-red radiation is used to treat strained muscles and tissue. Infrared radiation is also used to diagnose tumours. This works because a tumour emits more infrared radiation than healthy tissue does. This radiation can be detected on a thermogram — a photograph taken using infra-red radiation. We cannot see infrared radiation, therefore these are used in security lights & burglar alarms. IR is also used to send signals from one place to another including remote controls and date links over short distance.

Visible light

Visible light covers the range of wavelengths from 350–700 nm (from the size of a molecule to a protozoan). Our sun emits the most of its radiation in the visible range, which our eyes perceive as the colours of the rainbow. Our eyes are sensitive only to this small portion of the electromagnetic spectrum. Visible light has various applications.

Ultraviolet

Ultraviolet radiation has wavelengths of 10–310 nm (about the size of a virus). Young, hot stars produce a lot of ultraviolet light and bathe interstellar space with this energetic light. Ultraviolet waves have the next shortest wavelength after visible light. Ultraviolet radiation is found naturally in sunlight. The three main types of ultraviolet radiation, and some of their effects are given below.

Type	Frequency	Hazard
UV C	High	causes severe damage to cells
UV B	Medium	causes severe sunburn and damage to cells
UV A	Low	weaker effects than UV B

UV light has the following applications:

- Ultraviolet light is used by powerful telescopes like the Hubble Space Telescope to see far away stars.
- UVC is germicidal, destroying bacteria, viruses and moulds in the air, in water and on surfaces therefore used in laboratories for sterilization.
- UV light synthesizes vitamin D in skin, controls the endocrine system and is a painkiller.
- Used in state of the art air-handling units, personal air purifiers and swimming pool technology.
- Used to detect forged bank notes: they fluoresce in UV light; real bank notes don't.
- Used to identify items outside visible spectrum areas, known as 'black lighting'.

X-rays

X-rays range in wavelength from 0.01–10 nm (about the size of an atom). They are generated, for example, by super-heated gas from exploding stars and quasars, where temperatures are near a million to ten million degrees Celsius. X-rays have even shorter wavelengths than ultraviolet rays. They can penetrate soft tissue like skin and muscle and are used to take X-ray pictures of bones in body. X-rays damage cells and cause cancers. Radiographer precautions include wearing lead aprons and standing behind a lead screen to minimize exposure.

Gamma rays

Gamma rays have the shortest wavelengths, less than 0.01 nanometres (about the size of an atomic nucleus). This is the highest frequency and most energetic region of the electromagnetic spectrum. Gamma rays can result from nuclear reactions and from processes taking place in objects such as pulsars, quasars, and black holes. Gamma rays are sometimes used in treating cancer and in taking detailed images for diagnostic medicine. In high doses, gamma can kill normal cells and cause cancers. Gamma rays are used to sterilize foods and research equipment.

SATELLITE

"A satellite is any object that revolves around a planet in a circular or elliptical path." The moon is earth's original, natural satellite, and there are many man-made (artificial) satellites, usually closer to earth. The actual journey into space began October 4, 1957, when the Soviet Union launched Sputnik 1, the world's first orbital spacecraft, which orbited the world for three months. A month later the Soviets launched Sputnik 2 and its passenger Laika, a dog who has the distinction of being the first known living creature to escape earth and enter outer space. The space race was on, and in February of 1958, the United States launched Explorer 1.

The first communication satellite was launched on December 18, 1958. Signal Communication by Orbital Relay (SCORE), which broadcasted a Christmas message from President Eisenhower - "Peace on Earth, Good will toward men" - orbited the earth for 12 days until the batteries failed.

How Satellites are launched

Rockets (and, until recently, reusable spacecraft such as the Space Shuttle) launch satellites into orbits high above Earth. Just as a string can keep a spinning rock turning in a circle about your head, so Earth's gravity provides a centripetal (centre-seeking) force that keeps a satellite in orbit. On board gyroscopes stop satellites spinning off course due to variations in Earth's magnetic field; alternatively they are set spinning when they are released from the launch vehicle to achieve the same effect. Once in place, satellites are powered by large arrays of solar panels or even nuclear-powered electric motors.

Gravity and Satellite Orbits

As satellites orbit the Earth they are pulled back in by the force of the gravitational field. If they did not have any motion of their own they would fall back to Earth, burning up in the upper reaches of the atmosphere. Instead the motion of the satellite rotating around the Earth has a force associated with it pushing it away from the Earth. For any given orbit there is a speed for which gravity and the centrifugal force balance each other and the satellite remains in a stable orbit, neither gaining height nor losing it.

Obviously the lower the satellites orbit the Earth, the stronger the gravitational pull, and this means that the satellite must travel faster to counteract this pull. Further away the gravitational field is less and the satellite velocities are correspondingly less.

How do Communications Satellites Work?

Communications satellites receive information from **transmitters** on Earth (in an **uplink**) and beam it down to **receivers** elsewhere on the planet (in a **downlink**). Transmitters and receivers differ widely. While a communications satellite might relay a signal between one sender and receiver (fired up into space and back down again, with one uplink and one downlink), satellite broadcasts typically involve one or more uplinks (for one or more TV channels) and multiple downlinks (to ground stations or individual satellite TV subscribers).

Types of satellites based on orbits

There are essentially three types of Earth orbits: High Earth Orbit, Medium Earth Orbit, and Low Earth Orbit.

Escape Velocity

Escape velocity is the speed that an object needs to break free of a planet or moon's gravity well and leave it without further propulsion. For example, a spacecraft leaving the surface of Earth needs to be going 7 miles per second, or nearly 25,000 miles per hour to leave without falling back to the surface or falling into orbit. Since escape velocity depends on the mass of the planet or moon that a spacecraft is blasting off, a spacecraft leaving the moon's surface could go slower than one blasting off of the earth, because the moon has less gravity than the earth. On the other hand, the escape velocity for Jupiter would be many times that of earth's because Jupiter is so huge and has so much gravity.

Body	:	**Escape velocity**
Moon	:	2.38 km/sec
Earth	:	11.2 km/sec
Jupiter	:	60 km/sec

High Earth Orbit

When a satellite reaches exactly 35,786 kilometres from Earth's surface it enters a sort of "sweet spot" in which its orbit matches Earth's rotation. Because the satellite orbits at the same speed that the Earth is turning, the satellite seems to stay in place over a single longitude, though it may drift north to south. This special, high

Earth orbit is called **geosynchronous or geostationary**. Because geostationary satellites are always over a single location, they are useful for communication (phones, television, radio, etc.). In geostationary orbit, satellites covers move area as compared to other orbit but due to greater distance the signals are week and take more time to reach on earth.

Medium Earth Orbit (MEO)

Closer to the Earth, satellites in a medium Earth orbit move more quickly. This orbit ranges from 2000km to slightly below geostationary orbit. It covers less area as comped to geostationary satellites. Two medium Earth orbits are notable: the **semi-synchronous** orbit and the **Molniya** orbit. A semi-synchronous orbit is an orbit with a period equal to half the average rotational period of the body being orbited, and in the same direction as that body's rotation. The semi-synchronous orbit is a near-circular orbit about 20,200 kilometres above the surface. A satellite at this height takes 12 hours to complete an orbit. It is the orbit used by the Global Positioning System (GPS) satellites.

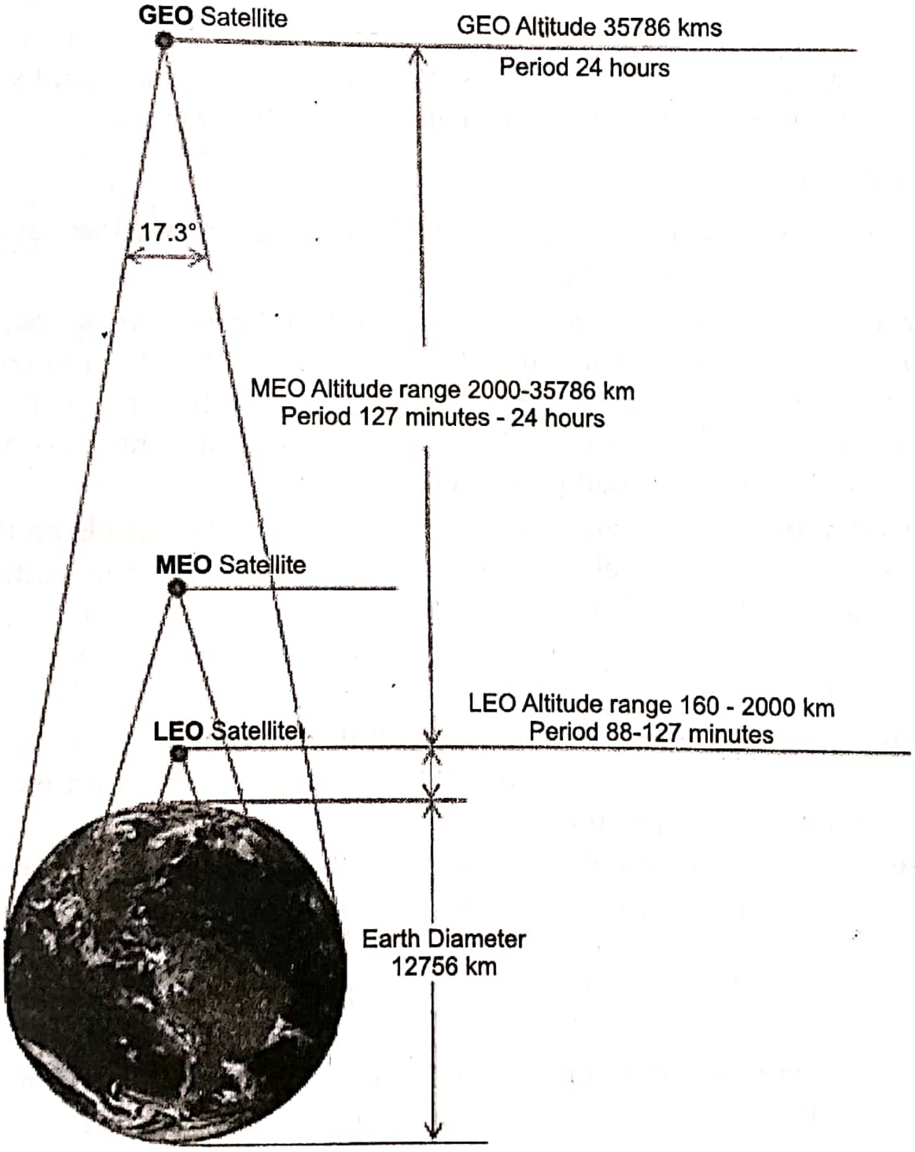


Fig: Satellite Orbits, Periods and Footprints

The second common medium Earth orbit is the Molniya orbit. Invented by the Russians, the Molniya orbit works well for observing high latitudes. A geostationary orbit is valuable for the constant view it provides, but satellites in a geostationary orbit are parked over the equator, so they don't work well for far northern or southern locations, which are always on the edge of view for a geostationary satellite. The Molniya orbit offers a useful alternative.

Low Earth Orbit

Most scientific satellites and many weather satellites are in a nearly circular, low Earth orbit (LEO). In LEO, satellites travel at height of 160km to 2000km. These satellite cover very small area but signal strength is excellent. LEO satellites can be polar & equatorial as well. Many of the satellites in NASA's Earth Observing System have a nearly polar orbit. In this highly inclined orbit, the satellite moves around the Earth from pole to pole, taking about 99 minutes to complete an orbit.

Just as the geosynchronous satellites have a sweet spot over the equator that lets them stay over one spot on Earth, the polar-orbiting satellites have a sweet spot that allows them to stay in one time. This orbit is a **Sun-synchronous orbit**, which means that whenever and wherever the satellite crosses the equator, the local solar time on the ground is always the same. For the Terra satellite, for example, it's always about 10:30 in the morning when the satellite crosses the equator in Brazil. When the satellite comes around the Earth in its next overpass about 99 minutes later, it crosses over the equator in Ecuador or Colombia at about 10:30 local time.

Structure of a satellite

Satellites have a great deal of equipment packed inside them. Most satellites have seven subsystems, and each one has special work to do.

1. **The propulsion subsystem** includes the rocket motor that brings the spacecraft to its permanent position, as well as small thrusters (motors) that help to keep the satellite in its assigned place in orbit. Satellites drift out of position because of solar wind or gravitational or magnetic forces. When that happens, the thrusters are fired to move the satellite back into the right position in its orbit.
2. The **power subsystem** generates electricity from the solar panels on the outside of the spacecraft. The solar panels also store electricity in storage batteries, which can provide power at times when the sun isn't shining on the panels. The power is used to operate the communications subsystem. The entire communications subsystem can be operated with about the same amount of power as would be used by 10 light bulbs.
3. The **communications subsystem** handles all the transmitting and receiving functions. It receives signals from the Earth, amplifies them, and transmits (sends) them to another satellite or to a ground station.
4. The **structures subsystem** helps provide a stable framework so that the satellite can be kept pointed at the right place on the Earth's surface. Satellites can't be allowed to jiggle or wander, because if a satellite is not exactly where it belongs, pointed at exactly the right place on the Earth, the television program or the telephone call it transmits to you will be interrupted.
5. The **thermal control subsystem** keeps the active parts of the satellite cool enough to work properly. It does this by directing the heat that is generated by satellite operations out into space, where it won't interfere with the satellite.
6. The **attitude control subsystem** points the spacecraft precisely to maintain the communications "footprints" in the correct location. When the satellite gets out of

position, the attitude control system tells the propulsion system to fire a thruster that will move the satellite back where it belongs.

7. **Operators** at the ground station need to be able to transmit commands to the satellite and to monitor its health. The telemetry and command system provides a way for people at the ground stations to communicate with the satellite..

Types of Satellites on the basis of application

Satellites can be classified by their function since they are launched into space to do a specific job. The type of satellite that is launched to monitor cloud patterns for a weather station will be different than a satellite launched to send television signals. The satellite must be designed specifically to fulfil its role. Different types are described below.

Weather Satellites

Weather satellites help meteorologists predict the weather or see what's happening at the moment. Typical weather satellites include the TIROS, COSMOS and GOES satellites. The satellites generally contain cameras that can return photos of earth's weather, either from fixed geostationary positions or from polar orbits.

Communications Satellites

Typical communications satellites include TELSTAR and INTELSAT. Communication satellites allow radio, television, and telephone transmissions to be sent live anywhere in the world. Satellite communications can complement existing terrestrial infrastructure, providing competitive advantages such as:

- Ubiquitous availability.
- Terrestrial-free network.
- Reliability.
- Multi-cast content distribution.
- Security & privacy.

Satellite communications provides advanced communications infrastructure to regions that do not have adequate terrestrial infrastructure through:

- Superior economics.
- Rapid deployment & installation.
- Flexibility & expandability.

Astronomical Satellites

An astronomical satellite is basically a really big telescope floating in space. Because it is in orbit above the earth, the satellite's vision is not clouded by the gases that make up the earth's atmosphere, and its infrared imaging equipment is not confused by the heat of the earth. The Hubble Space Telescope is the most famous scientific satellite.

Navigational Satellites

Navigational satellites help ships and planes navigate. GPS can provide position information with accuracy from 100 m (about 300 ft) to less than 1 cm (less than about 0.4 in).

Search and Rescue Satellites

Search and rescue satellites are designed to provide a way for vessels at sea and in the air to communicate from remote areas. These satellites can detect and locate emergency beacons carried by ships, aircraft, or individuals in remote or dangerous places.

Remote-sensing (Earth observation) Satellites

Remote-sensing satellites are usually put into space to monitor resources important for humans. For example, remote-sensing satellites might track animal migration, locate mineral deposits, watch agricultural crops for weather damage or see how fast the forests are being cut down.

Military Satellites (Reconnaissance Satellites)

Much of the actual application of information remains secret. Applications may include relaying encrypted communication, nuclear monitoring, observing enemy movements, early warning of missile launches, etc.

GLOBAL POSITIONING SYSTEM

The Global Positioning System (GPS) is a navigation system that allows land, sea and airborne users to determine their exact location, velocity and time 24 hours a day, in all weather conditions, from anywhere in the world. The system provides critical capabilities to military, civil, and commercial users around the world. The U.S. Air Force develops, maintains, and operates the space and control segments. Bradford Parkinson), an American engineer and inventor, and United States Air Force colonel is best known as the father of the Global Positioning System (along with Roger L. Easton and Ivan A. Getting).

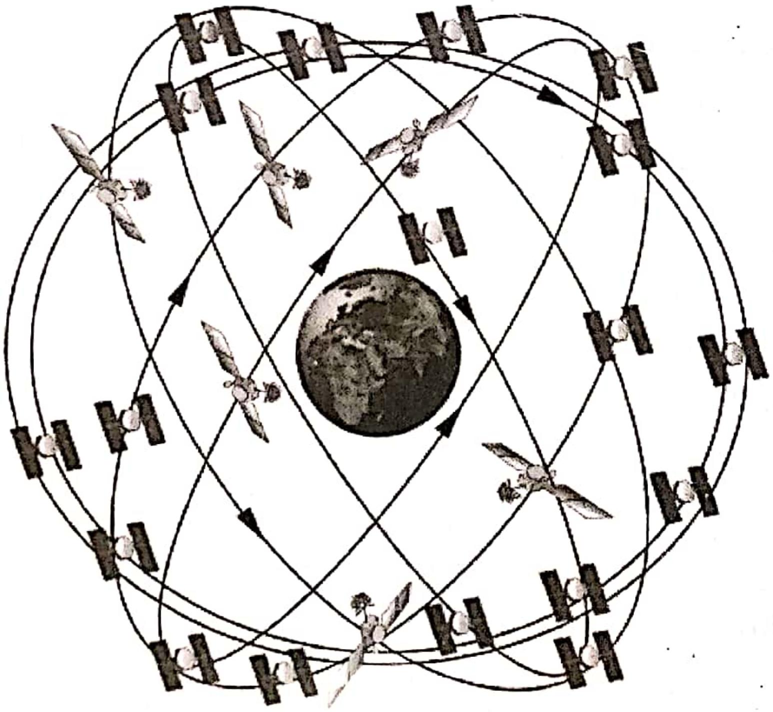


Figure: GPS Satellites

The Global Positioning System (GPS) is a U.S.-owned utility. This system consists of three segments: the **space segment, the control segment,** and **the user segment.**

Space segment

The fully operational GPS satellite system consists of a constellation of 24 operational satellites (currently 32 satellites in orbit 24 operational and 8 spare) with a few more in orbit as spares in case of the failure of one. The GPS satellites are in one of six orbits and fly in Medium earth orbit (MEO) at an altitude of approximately 20, 200km. Each satellite circles the earth twice a day. Each satellite contains a computer, an atomic clock, and a radio. With an understanding of its own orbit and the clock, it continually broadcasts its changing position and time. (Once a day, each satellite checks its own sense of time and position with a ground station and makes any minor correction.)

On the ground, any GPS receiver contains a computer that "**triangulates**" its own position by getting bearings from three of the four satellites. The result is provided in the form of a geographic position — longitude and latitude — to, for most receivers, within 100 metres. If the receiver is also equipped with a display screen that shows a map, the position can be shown on the map. If a fourth satellite can be received, the receiver can figure out the altitude as well as the geographic position. If you are moving, your receiver may also be able to calculate your speed and direction of travel and give you estimated times of arrival to specified destinations.

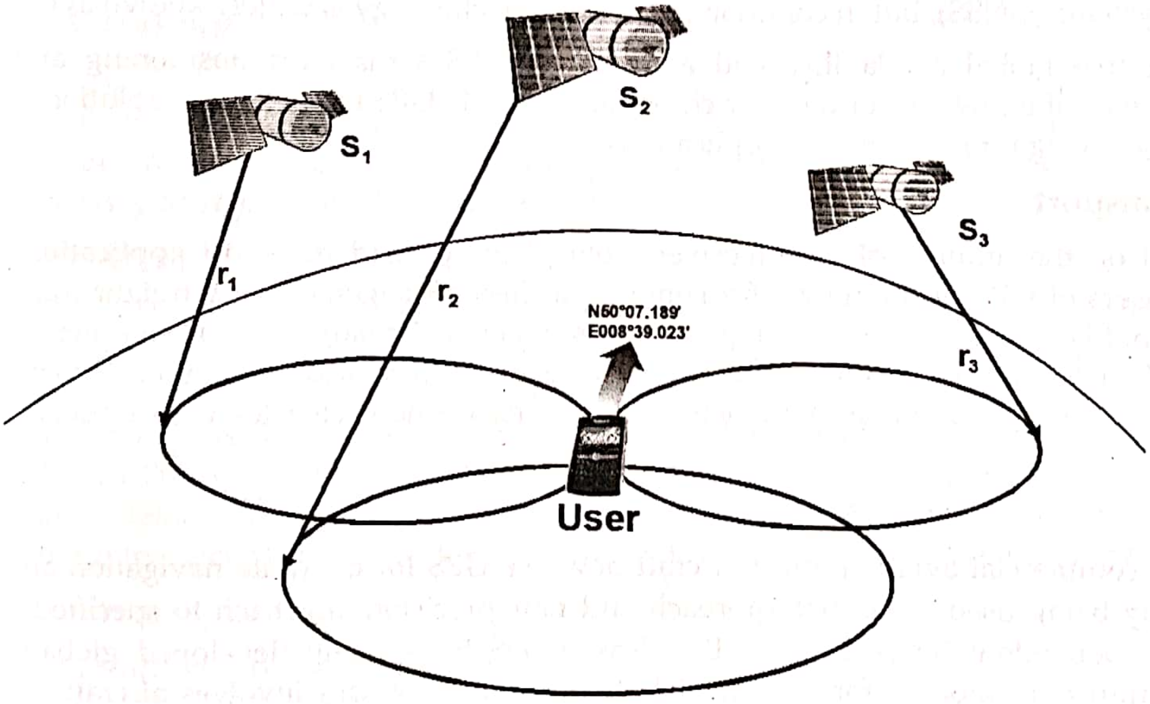


Figure: Triangulation

Control Segment

The GPS control segment consists of a global network of ground facilities that track the GPS satellites, monitor their transmissions, perform analyses, and send commands and data to the constellation. The current operational control segment includes a master control station, an alternate master control station, 11 command and control antennas, and 15 monitoring sites.

User Segment

In general, GPS receivers are composed of an antenna, tuned to the frequencies transmitted by the satellites, receiver-processors, and a highly stable clock (often a crystal oscillator). They may also include a display for providing location and speed information to the user. A receiver is often described by its number of channels: this signifies how many satellites it can monitor simultaneously. Originally limited to four or five, this has progressively increased over the years.

Applications of GPS

GPS is a satellite-based technology developed for and funded by the US Department of Defense over more than four decades. Its primary purpose is positioning infantry brigades and armoured divisions in a theatre of war, guiding aircraft, UAVs and munitions such as missiles and artillery shells to their targets, allowing military units operating behind enemy lines to navigate their way through hostile territory and provide accurate position-based intelligence back to headquarters.

Following the success of the United State's GPS satellite constellation, other nations have started deploying their own satellite systems. Russia has deployed GLONASS constellation, the European Union is working on a satellite system called Galileo and China has a constellation called BeiDou (a.k.a. Compass). Collectively these systems are known as Global Navigation Satellite Systems (GNSS), but in common parlance the technology is widely known as GPS.

The free global availability and accuracy of GPS signals for positioning and timing, combined with the low cost of receiver chipsets, has made GPS the preferred solution for a very wide and growing range of civilian applications.

Road Transport

Based on the number of GPS receivers sold globally, road transport applications are the majority users of GPS positioning – for commercial fleet management and freight tracking, taxi services, public transport monitoring and passenger information, and emergency vehicle location, dispatch and navigation. Private car owners have also widely adopted GPS navigation systems and most automobile manufacturers now release new vehicles with optional factory-fitted GPS.

Aviation

In commercial aviation, most aircraft now use GPS for en-route navigation and GPS is increasingly being used for initial approach and non-precision approach to specified airfields. Automatic Dependent Surveillance - Broadcast (ADS-B) is being developed globally as the preferred future technology for commercial air traffic control; this involves aircraft calculating their position using GPS and broadcasting it to other aircraft. GPS is also widely used for navigation of unmanned aerial vehicles (UAVs) for professional applications such as resource mapping and aerial surveying – imaging tasks previously performed by satellites such as NASA's Landsat.

Shipping & Rail Transport

Maritime applications include ocean and inshore navigation, dredging, port approaches, harbour entrance and docking, Vessel Traffic Services (VTS), Automatic Identification System

(AIS), hydrography, and cargo handling. Railway applications include the management of rolling stock, passenger information, preventing doors opening until the carriage is alongside the platform, cargo tracking signalling, train integrity and level crossing approach.

Science

Scientific applications of GPS are widespread and include environmental and atmospheric monitoring, animal behavior studies, botanical specimen location, meteorology and climate research. GPS is used in agriculture and fisheries for land area mapping, yield monitoring, precision planting of crops, spraying and harvesting, autonomous vehicle control and to monitor fishing limits.

Security

Security applications include tracking of vehicles, containers, other valuable cargoes and covert tracking of suspects and terrorists.

Surveying, Mapping and Geophysics

GPS is widely used in mapping, including aerial mapping, and other Geographical Information System (GIS) applications. In geophysics, GPS is used to time stamp seismic activity and to monitor position changes in sensitive physical formations such as volcanoes and earthquake fault lines.

Telecommunications

GPS timing is important for telecommunications applications, particularly for mobile telephone networks. Synchronous technologies are much more efficient than asynchronous technologies but require a time source with appropriate accuracy, stability and reliability to operate effectively or at all, and GPS satellites can provide this.

Financial Services

Global financial systems increasingly need precise timing systems to schedule and prioritise local and international money transfers, settlements and trades and to provide an audit trail for financial transactions. For example, the time signal provided by the atomic clocks on board the GPS satellites is used by financial institutions worldwide for providing date and time stamps for Electronic Funds Transfers. In some developed countries up to 80% of retail transactions involve either credit or debit cards. With millions of these transactions occurring every minute, a very high level of timing accuracy has become a critical component of financial trading networks.

Social Activities

Widely available, low-cost hand-held GPS receivers have enabled a numerous variety of social activities. The most ubiquitous application is in-car navigation, but there are dozens of other applications: GPS-based social networking, geotagging photographs, cross country cycling, hiking, skiing, paragliding, skydiving, geocaching, geodashing and other gaming activities.

REMOTE SENSING

"Remote sensing is the science (and to some extent, art) of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information."

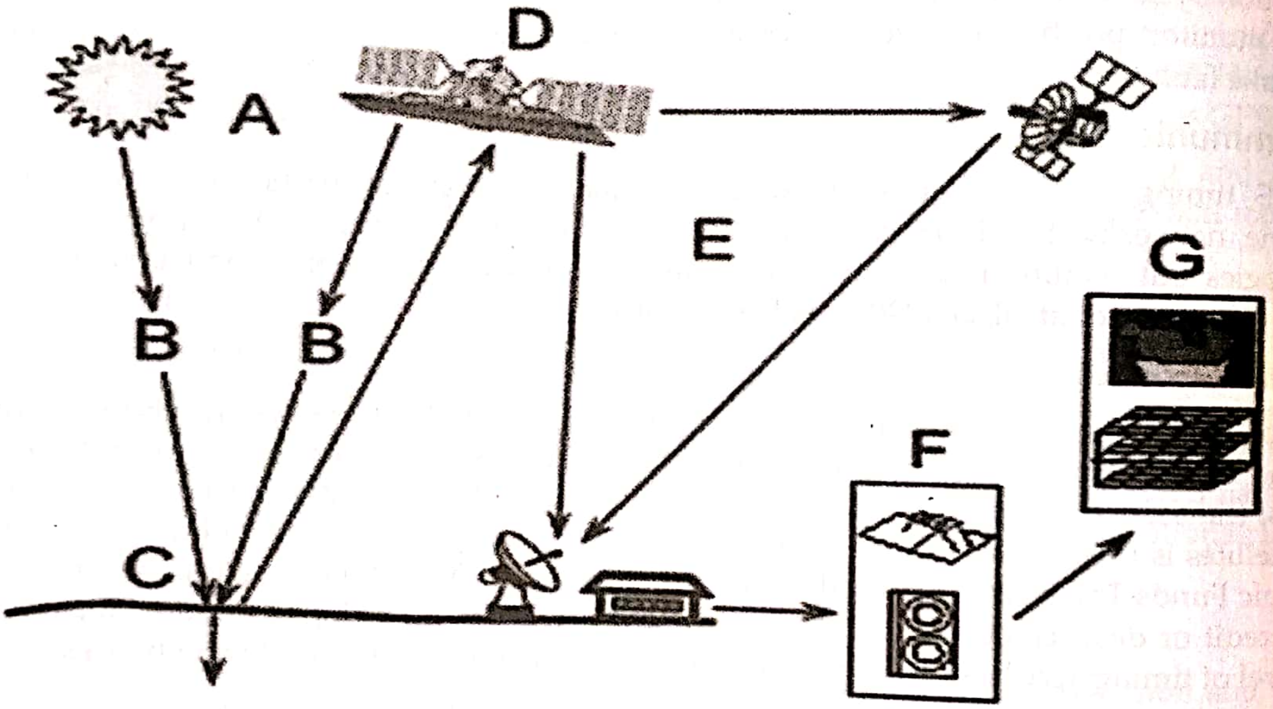
Remote Sensing: Basic Principle

Different objects on earth return (reflects or emits) different amount of incident energy in different wavelength ranges of the electromagnetic spectrum. Most remote sensing systems utilize the sun's energy, which is a predominant source of energy. Everything in nature has its own unique pattern of reflected, emitted or absorbed radiation. A sensor is used to record reflected or emitted energy from the surface. This recorded energy is then transmitted to the users and then it is processed to form an image, which is then analysed to extract information about the target. Finally the information extracted is applied to assist in decision making for solving a particular problem.

Basic components of a remote-sensing system include: **a target, an energy source, a transmission path,** and **a sensor.**

Process of Remote Sensing

The process involves an interaction between incident radiation and the targets of interest. This is exemplified by the use of imaging systems where the following seven processes are involved.



1. **Energy Source or Illumination (A)**—the first requirement for remote sensing is to have an energy source which illuminates or provides electromagnetic energy to the target of interest.
2. **Radiation and the Atmosphere (B)**— as the energy travels from its source to the target, it will come in contact with and interact with the atmosphere it passes through. This interaction may take place a second time as the energy travels from the target to the sensor.

3. **Interaction with the Target (C)** —once the energy makes its way to the target through the atmosphere, it interacts with the target depending on the properties of both the target and the radiation.
4. **Recording of Energy by the Sensor (D)** — after the energy has been scattered by, or emitted from the target, sensor collect and record the electromagnetic radiation.
5. **Transmission, Reception, and Processing (E)** —the energy recorded by the sensor has to be transmitted to a receiving and processing station where the data are processed into an image.
6. **Interpretation and Analysis (F)** — the processed image is interpreted to extract information about the target which was illuminated.
7. **Application (G)** —the final element of the remote sensing process is achieved when we apply the information we have been able to extract from the imagery about the target in order to better understand it, reveal some new information, or assist in solving a particular problem.

Types of Remote Sensing

Remote sensing can be classified on the basis of source of energy and range of electromagnetic spectrum. **Passive sensors** measure reflected sunlight that was emitted from the sun. **Active sensors** have its own source of light or illumination and its sensor measures reflected energy.

Passive Remote Sensing

The sun provides a very convenient source of energy for remote sensing. The sun's energy is either *reflected*, or absorbed and then *re-emitted*, in the form of thermal infra-red wavelengths. Remote sensing systems which measure this energy are called **passive sensors.** Passive sensors can only be used to detect energy when the naturally occurring energy is available. For all reflected energy, this can only take place during the time when the sun is illuminating the Earth. There is no reflected energy available from the sun at night. Energy that is naturally emitted (such as thermal infra-red) can be detected day or night, as long as the amount of energy is large enough to be recorded. Scientists use a variety of passive remote sensors.

Active Remote Sensing

Active sensors, on the other hand, provide their own energy source for illumination. The sensor emits radiation which is directed toward the target to be investigated. The radiation reflected from that target is detected and measured by the sensor.

Advantages for active sensors include the ability to obtain measurements anytime, regardless of the time of day or season. *Active sensors can be used for examining wavelengths that are not sufficiently provided by the sun,* such as microwaves, or to better control the way a target is illuminated. However, active systems require the generation of a fairly large amount of energy to adequately illuminate targets. Scientists use many different types of active remote sensors.

Active Remote sensors are weather independent as they can permeate cloud, light rain and snow. Similarly they as sunlight independent and can be operated day and night. There penetration is from mm to meters and can provide information about soil moisture content. However, there power is low and can be inflamed by other radiation sources.

Remote Sensing platforms

Platforms or remote sensors may be situated on the ground, on an aircraft or balloon or on a spacecraft or satellite outside of the Earth's atmosphere.

Ground-based sensors are often used to record detailed information about the surface which is compared with information collected from aircraft or satellite sensors. In some cases, this can be used to better characterize the target which is being imaged by these other sensors, making it possible to better understand the information in the imagery. Sensors may be placed on a ladder, tall building, crane, etc.

Aerial platforms are primarily stable wing aircraft, although helicopters are occasionally used. Aircraft are often used to collect very detailed images and facilitate the collection of data over virtually any portion of the Earth's surface at any time.

In space, remote sensing is conducted from **satellites**. Some of the most popular and valued remote sensing images of the Earth are obtained from the Landsat satellites which have been orbiting the Earth for over 40 years. Landsat 8, the newest Landsat, was launched on February 11, 2013.

Image Analysis

In order to take advantage of and make good use of remote-sensing data, we must be able to extract meaningful information from the imagery. Much interpretation and identification of targets in remote sensing imagery is performed manually or visually, i.e. by a human interpreter. Recognizing targets is the key to interpretation and information extraction. Observing the differences between targets and their backgrounds involves comparing different targets based on any, or all, of the visual elements of **tone, shape, size, pattern, texture, shadow, and association.**

When remote sensing data are available in digital format, **digital processing and analysis** may be performed using a computer. This interpretation can be done visually or electronically with the aid of computers and image processing software. The most common software used in remote sensing is ERDAS Imagine, ESRI, MapInfo, and ERMapper.

Types of Image Resolutions

The quality of remote sensing data consists of its spectral, radiometric, spatial and temporal resolutions.

Spatial Resolution

Spatial resolution refers to the size of the smallest object that can be resolved on the ground. In a digital image, the resolution is limited by the pixel size, i.e. the smallest resolvable object cannot be smaller than the pixel size. The pixel size is determined by the sampling distance.

A "High Resolution" image refers to one with a small resolution size and greater no of Pixels. Fine details can be seen in a high resolution image. On the other hand, a "Low Resolution" image is one with a large resolution size, i.e. only coarse features can be observed in the image and have less pixels. An image sampled at a small pixel size does not necessarily have a high resolution.

Radiometric Resolution

Radiometric resolution is the capacity of the instrument to distinguish differences in light intensity or reflectance. The greater the radiometric resolution, the more accurate the sensed image will be. Radiometric resolution is routinely expressed as a bit number, typically in the range of 8 to 16 bits. The radiometric resolution of an imaging system describes its ability to discriminate very slight differences in energy. The finer the radiometric resolution of a sensor, the more sensitive it is to detecting small differences in reflected or emitted energy.

Spectral Resolution

Spectral resolution describes the ability of a sensor to define fine wavelength intervals. The finer the spectral resolution, the narrower the wavelength range for a particular channel or band.

Black and white film records wavelengths extending over much, or all of the visible portion of the electromagnetic spectrum and have low spectral resolution. Many remote sensing systems record energy over several separate wavelength ranges at various spectral resolutions. These are referred to as **multi-spectral sensors.** Advanced multi-spectral sensors called **hyperspectral** sensors, detect hundreds of very narrow spectral bands throughout the visible, near-infra-red, and mid-infra-red portions of the electromagnetic spectrum. High spectral resolution facilitates fine discrimination between different targets based on their spectral response in each of the narrow bands.

Temporal Resolution

The ability to collect imagery of the same area of the Earth's surface at different periods of time is one of the most important elements for applying remote sensing data. For example, during the crop growing season, most species of vegetation are in a continual state of change and our ability to monitor those subtle changes using remote sensing is dependent on when and how frequently we collect imagery. By imaging on a continuing basis at different times we are able to monitor the changes that take place on the Earth's surface. So the images that are taken with shorter interval of time say for example after every 2 hrs will have higher temporal resolution than the image taken after 24 hours or one week.

Advantages of Remote Sensing

The principal advantages of remote sensing are the speed at which data can be acquired from large areas of the earth's surface, and the related fact that comparatively inaccessible areas may be investigated in this way. The major advantages of this technique over ground-based methods are summarized as follows:

1. Remote-sensing process facilitates the study of various earth's surface features in their spatial relation to each other and helps to delineate the required features and phenomena.
2. The remote-sensing satellites provide repetitive coverage of the earth and this temporal information is very useful for studying landscape dynamics and variations of vegetation etc.
3. Remote-sensing process made it possible to gather information about the area when it is not possible to do ground survey like in mountainous areas and disaster hit areas.
4. Since information about a large area can be gathered quickly, the techniques save time and efforts of human. It also saves the time of fieldwork.

5. Remote sensing especially when conducted from space, is an intrinsically expensive activity. Nevertheless, cost-benefit analysis demonstrates its financial effectiveness. It is a cost-effective technique as again and again fieldwork is not required and also a large number of users can share and use the same data.

Applications of Remote Sensing

Remote sensing has extensive applications in many fields of science and research. Applications of remote sensing can be applied to geology, hydrology, mining, fisheries, cartography, geography, biology environmental studies, geographic information systems, meteorology, agriculture, forestry, land development and resource management.

Some important remote sensing applications are listed below:

1. **In Geology:** Geology has a long history of remote sensing applications. The existing geological maps have been updated.
2. **In Agriculture:** Remote sensing provides important data for crop identification and area measurement under different types of crops. The total area under various crops has been effectively estimated using remote sensing. Remote sensing can help raise the productivity of food grains.
3. **In Forestry:** Remote sensing helps in providing information about the extent of forest cover. It also gives a general idea of the types of forest cover. It also helps in the detection of forest hazards like fire, disease and excessive felling. It also helps in biomass and fuel-wood assessments.
4. **In Land use mapping:** Remote sensing data can be used to great advantage in up-to-date land use pattern of large areas at any given time. The changes that occur from time to time can also be monitored.
5. **Remote sensing can also provide data related to ocean and coastal zones:** The potential area of fish concentration can be identified. Environmental degradation that takes place in coastal zones due to overexploitation can also be monitored.
6. **Remote sensing has become a valuable tool in monitoring environmental conditions:** The impact of mining activities on environment could not have been known without the help of remote sensing.
7. **In biodiversity:** Satellite-based remote sensing has helped to capture details of the Earth's surface to understand the distribution and status of biodiversity.
8. **In Urban Planning:** Remote sensing helps us in planning pipeline routes, ring roads, mass transit systems and urban settlements.
9. **Disaster damage assessment:** Remote sensing techniques have been found to be highly effective in disaster damage assessment.

A few of the projects undertaken by SUPARCO in the recent past are highlighted below.

Agriculture

Crop monitoring, forecasting and estimation is being carried out around the year using satellite remote sensing and other technologies to fortify food security and allied disciplines in Pakistan. A pragmatic beginning was made by providing production statistics of three contiguous districts of cotton-wheat zone in Punjab and Sindh in 2005-06. The project area was expanded subsequently to 44 districts during 2006-07 and now entire country is being covered for monitoring, forecasting and estimation of wheat, cotton, rice, sugarcane, and maize crops throughout the year. A monthly agriculture bulletin is also being issued and can be accessed on the SUPARCO web site www.suparco.gov.pk/pages/pak-scms.asp.

Forestry

Satellite image based forest resource mapping and updating, forest change detection, forest resource inventory and GIS database development are some of the features that are being applied in forestry. Remote sensing is providing baseline information for planning of afforestation strategies, futuristic resource planning, sustainability of environment wildlife conservation and development for recreation purpose. Mangrove and coastal forests are being monitored through remote sensing.

Disaster monitoring and mitigation

Remote sensing satellites can provide accurate and timely information of the disaster affected areas. Since the earthquake of 2005, SUPARCO has provided satellite imagery, damage assessment reports and other information to the disaster management and mitigation agencies. The turnaround time from a disaster occurring in Pakistan to the provision of imagery is less than two days. SUPARCO has also been involved in contingency planning in collaboration with UN agencies.

Land Use Mapping of AJK

Azad Jammu and Kashmir (AJK) government requested SUPARCO for the provision of latest information on land use, urban sprawl mapping and infrastructure. The latest satellite imagery was acquired for land use and urban sprawl mapping. A digital elevation model was developed and used for elevation information. It was supplemented with extensive ground surveys by SUPARCO / AJK teams. A database with special reference to education and health facilities in the AJK has also been developed.

GEOGRAPHIC INFORMATION SYSTEMS (GIS)

Geographic Information Systems is relatively a new concept therefore many people offer different definitions of GIS. In the range of definitions presented below, different emphases are placed on various aspects of GIS.

- A GIS is "an organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information." Redlands CA: Environmental System Research Institute, 1990
- A GIS is a computer system capable of capturing, storing, analyzing, and displaying geographically referenced information; that is, data identified according to location. U.S. Geological Survey (USGS)

One reason why it can be difficult to agree on a single definition for GIS is that various kinds of GIS exist, each made for different purposes and for different types of decision making. A variety of names have been applied to different types of GIS to distinguish their functions and roles. The use of so many acronyms, synonyms, and terms with related meaning can cause some confusion. Consider a few of the most widely used terms:

- AGIS (Automated Geographic Information System)

- AM/FM (Automated Mapping and Facilities Management)
- CAD (Computer-Assisted Drafting)
- CAM (Computer-Assisted Mapping,
- Environmental Information System
- Geographically Referenced Information System
- LIS (Land Information System)

John Snow and GIS

In 1854 there was a massive cholera outbreak in Soho, London – in three days over 120 people died from the disease. John Snow, a physician, created a map that showed the relationship between cholera and the public sources of water in Soho England. Famously, John Snow plotted the locations of the deaths on a map and found they clustered around a pump in Broad Street – he suggested that the pump be taken out of service – thus helping to end the epidemic. This then helped him formulate his theory of the spread of cholera by dirty water.

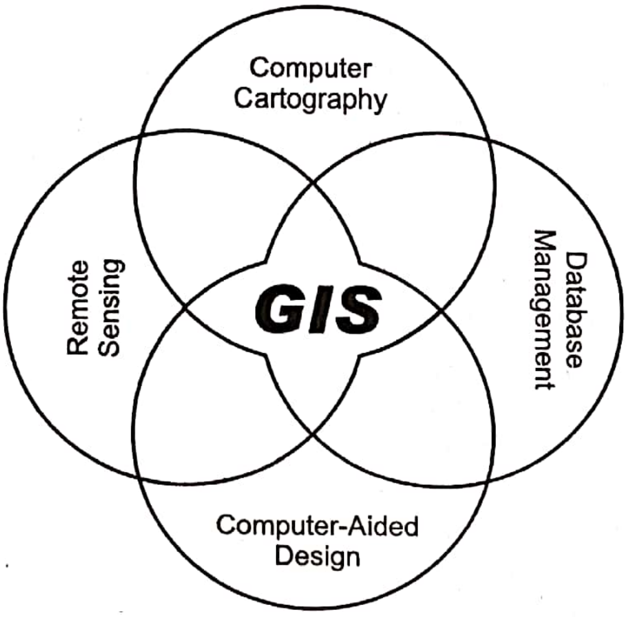
This analysis is famous as it is often considered to be:

- The first **epidemiological analysis** of disease – trying to understand the spread of cases by factors in the environment
- The first **geographical analysis** of disease data – plotting points on a map and looking for relationships

Snow's work is often used as a case study in courses in GIS and the geographies of health. This was one of the earliest successful uses of a geographic methodology in epidemiology. While the basic elements of topography and theme existed previously in cartography, the John Snow map was unique, using cartographic methods not only to depict but also to analyze clusters of geographically dependent phenomena. Dr. Roger Tomlinson (1933-2014) is generally recognized as the "father of GIS."

GIS as an Integrating Technology

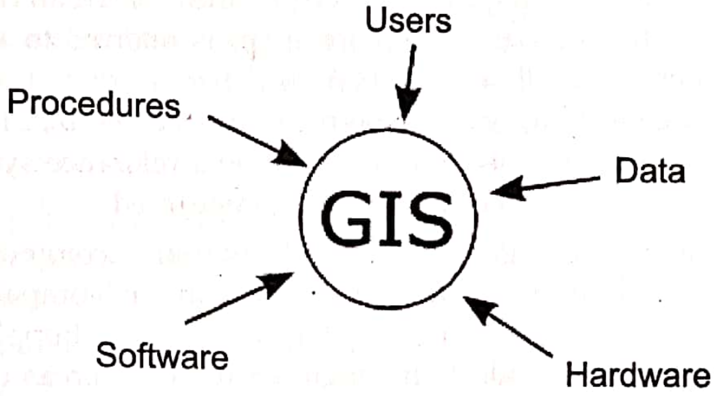
Geographic information systems have served an important role as an integrating technology. With GIS it is possible to map, model, query, and analyse large quantities of data all held together within a single database.



The importance of GIS as an integrating technology is also evident in its pedigree. The development of GIS has relied on innovations made in many different disciplines: Geography, Cartography, Photogrammetry, Remote Sensing, Surveying, Geodesy, Civil Engineering, Statistics, Computer Science, Operations Research, Artificial Intelligence, Demography, and many other branches of the social sciences, natural sciences, and engineering have all contributed.

Components of GIS

A working GIS integrates five key components: hardware, software, data, people, and procedures.



Hardware: Hardware is the computer on which a GIS operates. Today, GIS software runs on a wide range of hardware types, from centralized computer servers to desktop computers used in stand-alone or networked configurations.

Software: GIS software provides the functions and tools needed to store, analyze, and display geographic information. Key software components are

- Tools for the input and manipulation of geographic information
- Tools that support geographic query, analysis, and visualization
- A graphical user interface (GUI) for easy access to tools

Data: Possibly the most important component of a GIS is the data. Geographic data and related tabular data can be collected in-house or purchased from a commercial data provider. A GIS will integrate spatial data with other data resources and can even use a DBMS, used by most organizations to organize and maintain their data.

People: GIS technology is of limited value without the people who manage the system and develop plans for applying it to real-world problems. GIS users range from technical specialists who design and maintain the system to those who use it to help them perform their everyday work.

Procedures: A successful GIS operates according to a well-designed plan and business rules, which are the models and operating practices unique to each organization.

GIS Tasks

General purpose geographic information systems essentially perform five processes or tasks:

- Input

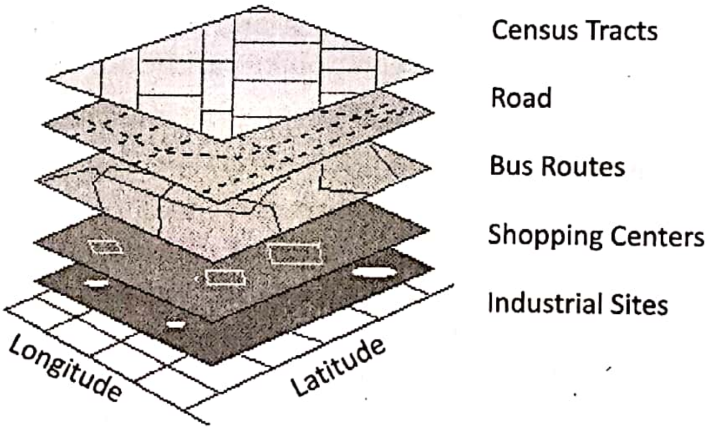
- Manipulation
- Management
- Query and Analysis
- Visualization

How GIS Works?

GIS provide powerful tools for addressing geographical and environmental issues. Consider the schematic diagram below. Imagine that the GIS allows us to arrange information about a given region or city as a set of maps with each map displaying information about one characteristic of the region.

In the diagram below, a set of maps that will be helpful for urban transportation planning have been gathered. Each of these separate thematic maps is referred to as a layer, coverage, or level. And each layer has been carefully overlaid on the others so that every location is precisely matched to its corresponding locations on all the other maps. The bottom layer of this diagram is the most important, for it represents the grid of a locational reference system (such as latitude and longitude) to which all the maps have been precisely registered.

Once these maps have been registered carefully within a common locational reference system, information displayed on the different layers can be compared and analyzed in combination. Transit routes can be compared to the location of shopping malls, population density to centers of employment. In addition. Single locations or areas can be separated from surrounding locations, as in the diagram below, by simply cutting all the layers of the desired location from the larger map. Whether for one location or the entire region, GIS offers a means of searching for spatial patterns and processes.



Types of GIS

There are a number of Geographical Information Systems (GIS) (or GIS software) available today. They range from high-powered analytical software to visual web applications, and each of those are used for a different purpose. We will cover three groups of GIS desktop GIS, Geo-browser and Web-based GIS.

Desktop GIS

A GIS, or GIS software, allows you to interactively work with spatial data. A desktop GIS is a mapping software that needs to be installed onto and runs on a personal computer. ArcGIS is used for a vast range of activities, covering both commercial and educational uses.

Arc
ESRI GIS™

ESRI®

Geobrowser

A geobrowser can be understood as an Internet Explorer for geographic information. Like the internet it allows the combination of many types of geographic data from many different sources. The biggest difference between the World Wide Web and the geographic web however is that everything within the latter is *spatially referenced*. **Google Earth** is the most popular geobrowser available and will be the one used for this course.

Web-based GIS

Web-based GIS, or WebGIS, are online GIS applications which in most cases are excellent data visualisation tools. Their functionality is limited compared to software stored on computer, but they are user-friendly and particularly useful as they not required data download. There are many WebGIS available: the Office of National Statistics (ONS) Neighbourhood mapping tool and the London Profiler.

Applications of GIS

There are huge ranges of applications of GIS, which generally set out to fulfil the five Ms of GIS: *mapping, measurement, monitoring, modelling, and management*. Uses of GIS range from indigenous people, communities, research institutions, environmental scientists, health organizations, land use planners, businesses, and government agencies at all levels.

Urban Planning

- Zoning, subdivision zoning, subdivision planning
- Land acquisition
- Economic development
- Law enforcement
- Housing renovation programmes
- Emergency response
- Crime analysis
- Tax assessment
- Disaster Management

Environmental Sciences

- Monitoring environmental risk
- Modelling storm water runoff
- Management of watersheds, floodplains, wetlands, forests, aquifers
- Environmental Impact Analysis
- Groundwater modelling and contamination tracking

Political Science

- Redistricting
- Analysis of election results
- Predictive modelling

Civil Engineering/Utility

- Locating underground facilities
- Designing alignment for freeways, transit, etc
- Coordination of infrastructure maintenance

Business

- Demographic analysis
- Market penetration/ share analysis
- Site Selection

Education Administration

- Attendance area maintenance
- Enrolment projections
- School bus routing

Real Estate

- Neighbourhood land prices
- Traffic impact analysis

Health Care

- Epidemiology
- Needs analysis
- Service inventory

GEOSPATIAL TECHNOLOGIES (MCQS)

Note: Answers are Bold and Underlined:

1. **The first geostationary satellite launched in 1965 was called:**
   (a) Sputnik
   (b) **EARLY BIRD (Intelsat-I)**
   (c) WESTAR
   (d) MOLNIYA
2. **Which of the following are key application disciplines for GIS?**
   (a) Civil engineering
   (b) Environmental sciences
   (c) Commerce and business
   (d) **All of theses**

3. **It is 'a set of tools for collecting, storing, retrieving at will, transforming, and displaying spatial data from the real world for a particular set of purposes' is a well used definition of a:**

(a) GIS
(b) GPS
(c) Remote sensing
(d) MIS

4. **Which of the following list is the key area of GIS functionality missed out by the above definition?**

(a) Re-projection
(b) Mapping
(c) Analysis
(d) Collation

5. **Which of the following is not an example of spatial data?**

(a) Lines showing the route of linear objects.
(b) Points showing location of discrete objects.
(c) Times of particular events.
(d) Polygons showing the area occupied by a particular land use or variable.

6. **Spatial referencing is the process of which of the following?**

(a) Combing attribute values with locational information.
(b) Referencing geo-relational tables.
(c) Establishing the topology of spatial objects.
(d) Computing the reference between items in databases.

7. **Geographical Information Science can be defined as:**

(a) The application of GIS to a range of scientific disciplines.
(b) The epistemological study of GIS.
(c) The science behind GIS.
(d) The use of GIS to solve physical problems.

8. **A transponder is a satellite equipment which:**

(a) Receives a signal from Earth station and amplifies
(b) Changes the frequency of the received signal
(c) Retransmits the received signal
(d) Does all of the abovementioned functions

9. **A geosynchronous satellite:**

(a) Has the same revolution as that of rotation of Earth
(b) Has a circular orbit
(c) Rotates in the equatorial plane
(d) All of these

10. **A geostationary satellite is one which:**

(a) Hangs motionless in space about 36,000 km about Earth
(b) Travels around the Earth in 24 hours
(c) Remains stationary above the Earth
(d) All of these

11. **Whole world can be covered with minimum:**

(a) One geo-stationary satellites (b) Three geo-stationary satellites

(c) Four geo-stationary satellites (d) Five geo-stationary satellites

12. **The escape velocity of the earth is approximately:**

(a) 11.2 km/s (b) 25 mi/hr (c) 35 m/s (d) 60km/s

13. **A satellite remains in orbit because the centrifugal force caused by its revolution around the Earth is counterbalanced by Earth's __________ :**

(a) Acceleration (b) Inertia (c) Gravitational pull (d) Speed

14. **Which of the following is a typical output from the GPS receiver?**

(a) Position (b) Speed (c) Time (d) All of these

15. **The operational satellites of Navstar GPS are revolving around Earth in ____ orbital planes.**

(a) 4 (b) 3 (c) 5 (d) 6

16. **Orbiting satellite system in Russia which means "lightning" or "news flash", used for television broadcasting. It uses a highly inclined elliptical orbit with apogee at about 40,000 km and perigee at about 1,000 km is called:**

(a) Molniya system (b) Molnya system

(c) Molnia system (d) All of these

17. **____________ means the farthest distance from earth a satellite orbit reaches while ____________ is the minimum distance.**

(a) Apogee and perigee (b) Perigee and apogee

(c) Aphelion and Perihelion (d) None of these

18. **Low Earth Orbit (LEO) satellites has rotation period of:**

(a) 70 to 80 min (b) 80 to 90 min (c) 90 to 100 min (d) 90 to 120 min

19. **Low Earth Orbit (LEO) satellites are close to:**

(a) Sun (b) Moon (c) Mars (d) Earth

20. **Low Earth Orbit (LEO) are below an altitude of:**

(a) 4000 kms (b) 3500 kms (c) 2000 kms (d) 1500 kms

21. **What is the name of the Russian equivalent of GPS?**

(a) KONOS (b) GPESKI (c) GLASNOST (d) GLONASS

22. **How many total satellites are currently being used in the US NAVSTAR GPS?**

(a) 24 (b) 15 (c) 25 (d) 32

23. **GPS stands for ____________ :**

(a) Geographic Positioning Services (b) Global Position Services

(c) Global Positioning System (d) Geographic Positioning System

24. **A GPS device can accurately pinpoint your location within ____________ :**

(a) a half mile (b) 10 metres (c) 500 feet (d) 10 feet

25. GPS technology uses ____________ :

(a) A network of cellular towers
(b) **A system of satellites**
(c) A series of interlinked microwave towers
(d) Continuous television transmission signals

26. Who built and operates the Global Positioning System?

(a) Pentagon
(b) **US Air Force**
(c) The United Nations
(d) NASA

27. A map maker is called a:

(a) Geographer
(b) **Cartographer**
(c) Map quester
(d) Photographer

28. Remote sensing device is:

(a) Deployed online
(b) Deployed from a computer
(c) **Deployed from a plane or satellite**
(d) Always done close up

29. Sensing that uses heat or temperature to detect is called:

(a) Radar Sensing
(b) Microwave Sensing
(c) Sonar Sensing
(d) **Infrared Sensing**

30. Infrared sensing is used to help map:

(a) **Animals and plants**
(b) Animals that have died
(c) Non-living objects
(d) Cold-blooded organisms

31. Microwave sensing uses:

(a) Heat and temperature
(b) **Long wavelengths**
(c) Short wavelengths
(d) Sound waves

32. Which two sensing methods bounce waves of an object and back to detect things?

(a) Touch and tasting
(b) **Radar and sonar**
(c) Radar and infrared
(d) Microwave and sonar

33. Sound waves are used in what type of sensing?

(a) Radar
(b) Microwave
(c) **Sonar**
(d) Infrared

34. Radio wave is very beneficial because it can penetrate thick:

(a) Sand and very dry objects
(b) Walls and concrete
(c) **Clouds and moisture**
(d) Steel and wood

35. Which of the following is true about the frequency and velocity of electromagnetic waves?

(a) **As frequency increases, wavelength decreases.**
(b) As frequency increases, wavelength increases.
(c) Frequency is constant for all wavelengths.
(d) Frequency and wavelength are independent of each other.

36. Compared with light waves, radio waves:

(a) Have higher energy
(b) Are higher frequency
(c) Are not composed of photons
(c) **Have longer wavelengths**

37. **Which of the following are electromagnetic waves?**
(a) Radio waves
(b) Optical light
(c) X-rays
(d) All of these

38. **The following are electromagnetic waves except:**
(a) Infrared waves
(b) Gamma rays
(c) Radio Waves
(d) Sound waves

39. **Electromagnetic waves are:**
(a) Longitudinal
(b) Transverse
(c) Both longitudinal and transverse
(d) None of these

40. **Which of the following correctly lists electromagnetic waves in order from longest to shortest wavelength?**
(a) Gamma rays, ultraviolet, infrared, microwaves.
(b) Microwaves, ultraviolet, visible light, gamma rays.
(c) Radio waves, infrared, gamma rays, ultraviolet.
(d) Radio waves, infrared, visible light, X-rays.

41. **A radar which detects the presence of an enemy aircraft uses:**
(a) Sound waves
(b) Radio waves
(c) Electric waves
(d) Ultrasonic waves

42. **Which of the following have the shortest wavelength?**
(a) Radio waves
(b) Infrared rays
(c) Ultraviolet Rays
(d) X-rays

43. **The frequency of radio waves lies in the range from:**
(a) 20Hz to 20 KHz
(b) 3 kHz to 300 GHz
(c) 600 MHz
(d) Above 600 MHz

44. **Which of the following are not deflected by electric and magnetic fields?**
(a) X-rays
(b) Electrons
(c) Beta rays
(d) Alpha rays

45. **Sound waves in air are:**
(a) Longitudinal
(b) Transverse
(c) Neither longitudinal nor transverse
(d) Stationary

CHAPTER 6

NATURAL HAZARDS AND DISASTERS

A disaster is a sudden, calamitous event that seriously disrupts the functioning of a community or society and causes human, material, and economic or environmental losses that exceed the community's or society's ability to cope using its own resources. Though often caused by nature, disasters can have human origins. (The International Federation of Red Cross and Red Crescent Societies).

$$\text{Disaster} = \frac{\text{Hazard} + \text{Vulnerability}}{\text{Capacity}}$$

The combination of hazards, vulnerability and inability to reduce the potential negative consequences of risk results in disaster.

Hazard can be defined as a threatening event, or probability of occurrence of a potentially damaging phenomenon within a given time period and area. ***Natural hazards*** are naturally occurring physical phenomena caused either by rapid or slow onset events which can be *geophysical* (earthquakes, landslides, tsunamis and volcanic activity), *hydrological* (avalanches and floods), *climatological* (extreme temperatures, drought and wildfires), *meteorological* (cyclones and storms/wave surges) or *biological* (disease epidemics and insect/animal plagues). ***Technological*** or ***man-made hazards*** (complex emergencies/conflicts, famine, displaced populations, industrial accidents and transport accidents) are events that are caused by humans and occur in or close to human settlements.

Vulnerability in this context can be defined as the diminished capacity of an individual or group to anticipate, cope with, resist and recover from the impact of a natural or man-made hazard.

Capacity, can be described as the resources available to individuals, households and communities to cope with a threat or to resist the impact of a hazard. Such resources can be physical technological, or material.

Scale of a Disaster

Scale of a disaster depends on:

- Lead time available.
- Intensity of hazard.
- Duration.
- Spatial extent.
- Density of population & assets.

- Time of occurrence.
- Vulnerability of elements at risk.

Elements at Risk

- People Livestock and wildlife
- Personal property, housing universities and hospitals
- Crops, trees and forests
- Telephone, electric poles, sewerage system
- Communication network, roads, railways, airports
- Boats, shipping infrastructure, coast side buildings
- Irrigation infrastructure

Effects of Disasters

Disasters of all types can have primary, secondary, and tertiary effects.

- **Primary effects** occur as a result of the process itself. For example water damage during a flood or collapse of buildings during an earthquake, landslide, or hurricane.
- **Secondary effects** occur only because a primary effect has caused them. For example, fires ignited as a result of earthquakes, disruption of electrical power and water service as a result of an earthquake, flood, or hurricane, or flooding caused by a landslide into a lake or river.
- **Tertiary effects** are long-term effects that are set off as a result of a primary event. These include things like loss of habitat caused by a flood, permanent changes in the position of river channel caused by flood, crop failure caused by a volcanic eruption etc.

DISASTER MANAGEMENT SYSTEM

Disaster Management can be defined as the organization and management of resources and responsibilities for dealing with all humanitarian aspects of emergencies, in particular preparedness, response and recovery in order to lessen the impact of disasters.

Disaster Management Cycle

The disaster management cycle illustrates the ongoing process to reduce the impact of disasters, react during and immediately following a disaster, and take steps to recover after a disaster has occurred. There are four major elements or phases of disaster management. These do not always, or even generally, occur in isolation or in this precise order. Often phases of the cycle overlap and the length of each phase greatly depends on the severity of the disaster. The four phases of disaster management are:

MITIGATION Pre-disaster mitigation efforts	**PREPAREDNESS** Education, outreach and training, Emergency management planning
RESPONSE Immediate response affected	**RECOVERY** Post-disaster recovery plan

Mitigation (and Prevention)

Mitigation activities actually eliminate or reduce the probability of disaster occurrence, or reduce the effects of unavoidable disasters. Mitigation measures include:

- building codes;
- vulnerability analyses updates;
- zoning and land use management;
- building use regulations and safety codes;
- preventive health care; and
- public awareness education.

Mitigation will depend on the incorporation of appropriate measures in national and regional development planning. Its effectiveness will also depend on the availability of information on hazards, emergency risks, and the counter-measures to be taken. The mitigation phase, and indeed the whole disaster management cycle, includes the shaping of public policies and plans that either modify the causes of disasters or mitigate their effects on people, property, and infrastructure.

Preparedness

During the preparedness phase, governments, organizations, and individuals develop plans to save lives, minimize disaster damage, and enhance disaster response operations. Preparedness measures include:

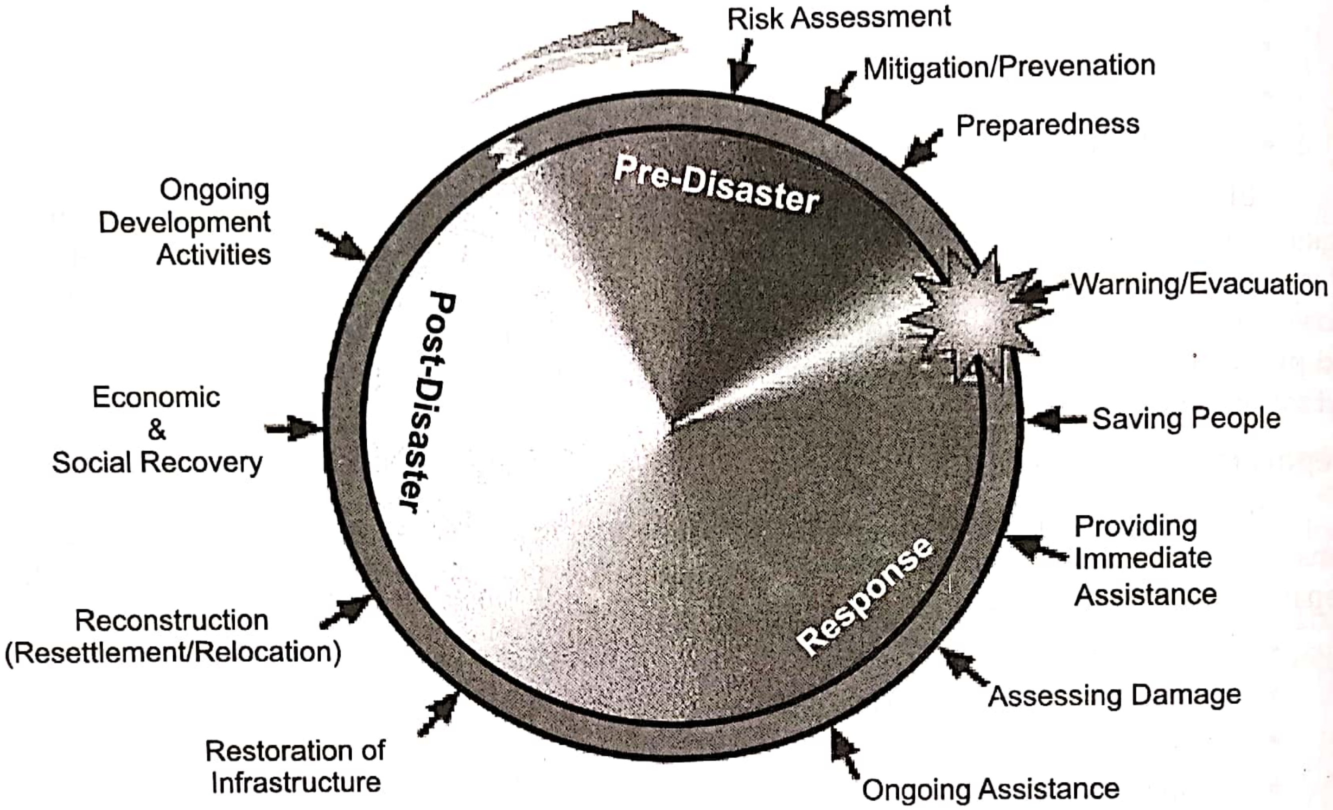
- preparedness plans;
- emergency exercises/training;
- warning systems;
- emergency communications systems;
- evacuations plans and training;
- resource inventories;
- emergency personnel/contact lists;
- mutual aid agreements; and
- public information and education.

Response

The aim of emergency response is to provide immediate assistance to maintain life, improve health and support the morale of the affected population. Such assistance may range from providing specific but limited aid, such as assisting refugees with transport, temporary shelter, and food, to establishing semi-permanent settlement in camps and other locations. It also may involve initial repairs to damaged infrastructure. The focus in the response phase is on meeting the basic needs of the people until more permanent and sustainable solutions can be found. Humanitarian organizations are often strongly present in this phase of the disaster management cycle.

Recovery

As the emergency is brought under control, the affected population is capable of undertaking a growing number of activities aimed at restoring their lives and the infrastructure that supports them. There is no distinct point at which immediate relief changes into recovery and then into long-term sustainable development. There will be many opportunities during the recovery period to enhance prevention and increase preparedness, thus reducing vulnerability. Ideally, there should be a smooth transition from recovery to on-going development. Recovery activities continue until all systems return to normal or better.


Risk Assessment
Mitigation/Prevenation
Preparedness
Warning/Evacuation
Saving People
Providing Immediate Assistance
Assessing Damage
Ongoing Assistance
Restoration of Infrastructure
Reconstruction (Resettlement/Relocation)
Economic & Social Recovery
Ongoing Development Activities
Pre-Disaster
Response
Post-Disaster

The Disaster Risk Management Cycle

Disaster Management in Pakistan

A devastating earthquake struck in the north in October 2005 which exposed the vulnerability of the existing emergency and disaster-response apparatus. This led to the creation of the National Disaster Management Authority (NDMA) and provincial disaster management authorities afterwards. The National Disaster Management Authority is supposed to serve as the focal point and coordinating body to facilitate implementation of disaster management. Meanwhile, the Provincial Disaster Management Authorities are the provincial implementing bodies responsible for coordinating with ministries, departments and the District Disaster Management authorities (DDMAs) for disaster-risk management activities in the districts and also responsible for implementing policies and plans for emergency response in the districts.

Flaws in Disaster Management Framework in Pakistan

Disaster management system in Pakistan has following flaws:

- Disaster management in Pakistan basically revolves around flood disasters with a primary focus on rescue and relief. After each disaster episode the government incurs considerable expenditure directed at rescue, relief and rehabilitation.

- Applied disaster management policy sometimes carries strategic biases that are aimed at protecting locations and infrastructure of greater economic, political and strategic significance at the cost of areas and communities with lesser influence and importance.
- Within disaster management bodies in Pakistan, there is a dearth of knowledge and information about hazard identification, risk assessment and management, and linkages between livelihoods and disaster preparedness.
- Disaster management policy responses are not generally influenced by methods and tools for cost-effective and sustainable interventions.
- There are no long-term, inclusive and coherent institutional arrangements to address disaster issues with a long-term vision.
- Disasters are viewed in isolation from the processes of mainstream development and poverty alleviation planning.
- Disaster management, development planning and environmental management institutions operate in isolation and integrated planning between these sectors is almost lacking.
- State-level disaster preparedness and mitigation measures are heavily tilted towards structural aspects and undermine non-structural elements such as the knowledge and capacities of local people, and the related livelihood protection issues.
- Disaster and relief departments and organizations largely remain under-resourced, untrained, and lack importance within administrative hierarchy.

Recommendations

There is a need to implement integrated disaster management policy at national and provincial level. Government must invest in capacity building of the disaster management authorities. Moreover, capacity of vulnerable communities shall be enhanced through training, awareness and education. Research may be funded at different universities and research organizations to enhance the knowledge base. To conclude, there is a need of proper disaster management system that must not focus on emergency plans and recovery alone.

EARTHQUAKE

Earthquake is a sudden release of energy in the form of seismic waves that create vibrations in the earth crust as a result of abrupt movement of tectonic plates.

Causes of Earthquakes

The surface of the Earth is in continuous slow motion. This is plate tectonics. The plates cover the entire surface of the globe. Since they are all moving they rub against each other in some places (like the San Andreas Fault in California), sink beneath each other in others (like the Peru-Chile Trench along the western border of South America), or spread apart from each other (like the Mid-Atlantic Ridge).

At such places the motion isn't smooth--the plates are stuck together at the edges but the rest of each plate is continuing to move, so the rocks along the edges are distorted (what we call "strain"). As the motion continues, the strain builds up to the point where the rock cannot withstand further bending. With an abrupt move, the rock breaks. An earthquake is the shaking that radiates out from the breaking rock.

Cracks along which rocks slip are called faults. They may break through the ground surface, or be deep within the earth. The location on a fault where slip first occurs is called the **focus**, whereas the position directly above it on the ground surface is called the **epicentre.**

Earthquake can also occur due to **volcanic cruptions, isostatic adjustments** and some **localised causes** such as heavy drilling, nuclear experiments etc. Earthquakes rarely take place at the surface of the Earth but at some depth within it. Though focal depths are usually shallow, earthquakes have been detected as deep as 720 km. Based on the depth of the focus earthquakes can be classified as:

- **Shallow:** when the depth of origin is less than 60 km.
- **Intermediate:** when the depth of origin is between 60 and 300 km.
- **Deep:** when the depth of origin is greater then 300 km.

Seismic waves

There are two groups of earthquake waves called *body waves* and *surface waves*. Body waves travel from the earthquake focus in all directions whereas surface waves travel around the earth rather than through it. Surface waves are slower than body waves.

Measurement of earthquake

A seismograph detects the vibrations caused by an earthquake. It plots these vibrations on a paper. The strength, or magnitude, of an earthquake is measured using the Richter scale. The Richter scale is numbered 0-10. It should be understood that Richter scale is a logarithmic scale. What this means is an earthquake measuring 6.0 is 10 times more powerful than an earthquake measuring 5.0.

Effects of Earthquakes

Effects are often classified as primary and secondary impacts. *Primary effects* occur as a direct result of the ground shaking, e.g. buildings collapsing. *Secondary effects* occur as a result of the primary effects, e.g. tsunamis or fires due to ruptured gas mains. However possible effects are enlisted below.

Damage to structures: Causing partial or total collapse, damage to road and rail network, damage to utility carriers, etc. Earthquakes typically impact a huge area, spanning whole city, and many times, several cities.

Sea activity: Water level in the sea could rise suddenly, causing very high waves, several metres in height, which could then flood the coastal areas. These could give rise to tsunamis, causing damage to coastal areas.

Landslide and Avalanche: As earth shakes, in mountainous regions, huge chunks of land could fall/slide onto lower regions of the mountains. This could have several impacts, including changed topography, blocked roadways, damage to anything that comes in the way of the landslide or Avalanche massive damage to the structure which sits on the piece of sliding land – and to the houses and roads where the piece of land finally lands.

Socio-economic Losses: In addition to massive physical damage, earthquakes induce long-lasting human, psychological and socio-economic losses and deprivations. Buildings can be rebuilt and injuries can be healed, however, lives cannot be returned and souls cannot be repaired. What is left are destroyed homes, shattered families, homeless people, collapsed human determinations, charmless lives, terrorized children and terrified faces with stuck minds.

Environmental impacts: The built landscape may be destroyed. Fires can damage areas of woodland. Important natural and human landmarks may be lost.

Economic impacts: Shops and business may be destroyed. The damage to transport and communication links can make trade difficult. The cost of rebuilding a settlement is high.

Predicting an Earthquake

Earthquakes have very low predictability in short-term, i.e. in most cases, there is no warning – even a few minutes before an earthquake. However, in most cases, a much higher degree of predictability exists in long-term – in the sense that if a certain area is sitting on a fault line, it can be said that over a long period of time, there is a high risk of earthquake. However, whether the earthquake occurs within the next few minutes, few years, few decades – or, maybe a few centuries-might not be predicted.

Management of Earthquakes

Here are some tactics that might be applied for managing earthquakes and improving our societal sustainability against earthquakes:

Risk Assessment: Inspect, evaluate and document risk associated with existing buildings and infrastructure in earthquake-prone areas. Ensure that the risk assessment has been incorporated in governmental policies.

Risk Zoning: Carry out country wide seismic micro-zonation to minimize disaster damage. Based on the earthquake risk and ground conditions, areas can be divided into different zones marked with hazard categories. For instance, RED where no construction is allowed and can be used only for playgrounds and parks; YELLOW where single story buildings can be built whereas multi-story buildings are not allowed, etc.

Planning: Maintain a better planning, construction and mitigation practices before earthquake happen and provide critical and timely information to improve response after an earthquake. Incorporate lessons learnt from the earthquakes occurred in the past.

Research & Development: Allocate research and development budgets for science and technology related to earthquakes and disaster management. Enhance capacity building by improving cooperation between government departments.

Public Awareness: Maintain awareness of local population about earthquake risk and how to act during and after an earthquake. Earthquake related information should be included in school syllabus and children must be taught every aspect of the earthquakes.

Legislation: Approve legislation covering natural hazards and establish concrete goals for mitigation by strategically and intensively prompting steps. National policies must be proactive and widely understood. Local level administrations must adopt plans and strategies to meet dynamics of disaster.

Building Code: Develop national building code. Adopting and enforcing building code provisions reduce earthquake damage risk. Buildings must be constructed according to the design codes to withstand earthquake affects, i.e. earthquake-resistant structures.

Emergency Management: Prioritize emergency preparedness by ensuring that emergency plan and response procedures are in place. Rescue teams must be trained and efficient. Rescue attempts must be swift and massive in order to save lives and money.

VOLCANOES

A volcano is simply an opening or vent on the earth's surface through which molten magma, escape on to the earth's surface. The word, 'volcano' was made out of the name of a Roman god of a small island in the Mediterranean sea of Sicily called 'Volcan'. The area around Pacific Ocean is characterized by higher volcanic activity. In fact, the entire rim along the Pacific Ocean is called as the Ring of Fire, because of volcanic activity along this zone.

Causes of Volcanic Eruptions

Inside the earth, there is a red-hot liquid rock, called magma. Volcanoes happen when magma rises to the surface of the earth, which causes bubbles of gas to appear in it. This gas can cause pressure to build up in the mountain, and it eventually explodes. When the magma bursts out of the earth, it is called lava. Volcanoes can be formed in three ways as listed below.

1. **Via subduction.** The subducting slab dehydrates to form new melt that will rise through the crust to be erupted at the surface.
2. **Via rifting.** When two plates pull apart magma rises, producing volcanic eruptions at the surface.
3. At **"Hotspots"**. Hotspot do not necessarily occur along a plate boundary. Hot Spots are hot mantle plumes breaching the surface in the middle of a tectonic plate. So hotspot volcanoes can form in the middle of tectonic plates.

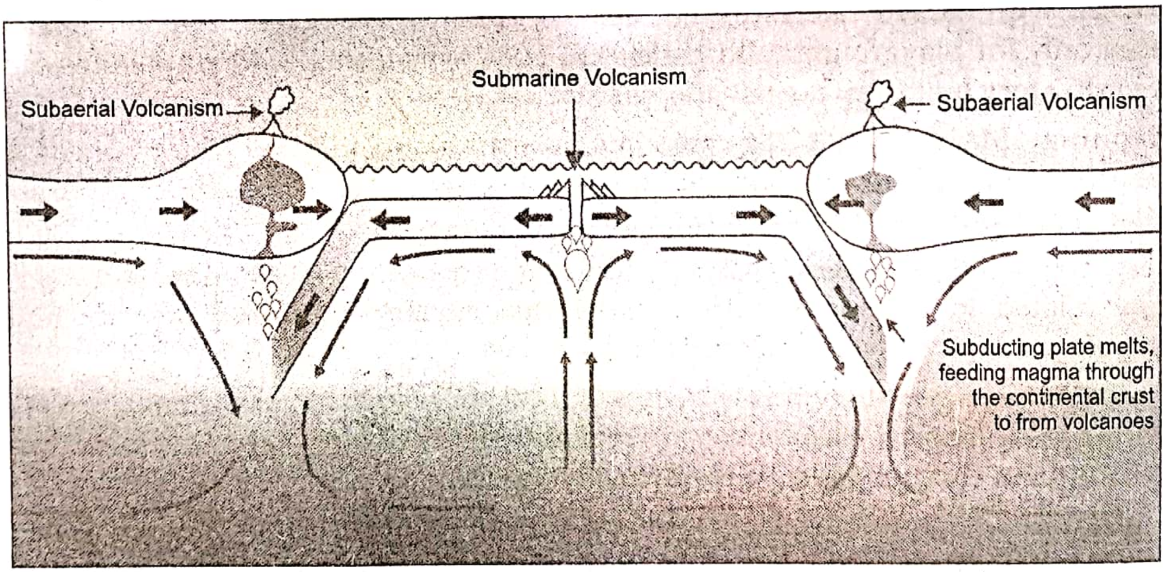

Subaerial Volcanism
Submarine Volcanism
Subaerial Volcanism
Subducting plate melts, feeding magma through the continental crust to from volcanoes

Figure: Formation of Volcanoes

The type of magma in the earth can create different volcanoes. If the magma is quite thin, the gas can escape easily and there will not be an explosion. The magma just comes out of the mountain and flows down the sides, like Volcanoes in Hawaii and Mount Etna.

But, if the magma is thick and sticky, the gas cannot escape, so it builds up and up until it explodes. This can cause landslides and sends out huge clouds of burning rock and gas, which devastate everything around them.

Classification of Volcanoes

Volcanoes can be described in terms of activity and can be:

1. **still active** and erupt frequently;
2. **dormant** (temporarily inactive but not fully extinct) and
3. **extinct** (never likely to erupt again).

Type Classifications

Volcanoes can also be described by their shape or type for example shield or composite volcanoes. A **shield volcano** is dome shaped and low. These volcanoes are mountains that have been shaped by the flows and can cover larger areas. The most common type of volcano is the strato or **composite**. These are tall mountains that have steep sides and which have alternated magma and layers of rock.

Effects of volcanic eruptions

1. Volcanic eruptions can be accompanied by earthquakes.
2. Volcanic activity in sea can trigger tsunamis.
3. Discharge of very high quantity of toxic material, poison the sources of water like lakes/rivers, etc. thereby severely disrupting the water supply.
4. Discharge of high amount of toxic gases in the atmosphere cause difficulty in breathing. Release of gases including oxides, sulfides, aerosols, etc. changes the atmospheric mix of the area. These in turn can give rise to acid rain.
5. Discharge of aerosols into the atmosphere alters the filtering impact of the atmosphere for sun's radiation as well as for heat from the earth getting radiated back into the space. This can change the temperature of the area.
6. Molten lava coming out of a volcano can reach temperatures up to 1200 degrees Celsius, thus, incarnate anything that comes in its way.
7. Lava flowing down at such a high temperature can cause structural damages
8. As lava flows down, it gets solidified, and, modifies the landscape. However, sometimes a fresh layer of lava at high temperature could destabilize the earlier solidified layer, and, that layer could simply slide off causing a landslide.
9. Lack of drinking water and breathable air causes people to migrate from their existing place of living to other places, thereby causing situations of migration and refugees.

TSUNAMI

Tsunami is a Japanese word meaning "harbour wave," and used as the scientific term for a class of abnormal sea wave that can cause catastrophic damage when it hits a coastline. A **tsunami** is a series of waves caused by a rapid displacement of a body of water (ocean, lake). Almost 80% of tsunamis occur within the Pacific Ocean's 'Ring of Fire'. This is due to the amount of earthquake and volcanic activity in the area, which occur due to the tectonic shifts in the earth's plates.

Causes of Tsunami

Tsunamis can be generated by an undersea *earthquake,* an undersea *landslide,* the eruption of an undersea *volcano,* or by the force of *an asteroid* crashing into the ocean. The most frequent cause of tsunamis is an undersea earthquake. When the ocean floor is uplifted or offset during an earthquake, a set of waves is created similar to the concentric waves generated by an object dropped into the water.

Formation of Tsunami

Tsunamis arise from the sudden displacement of gigantic water masses due to earthquakes on the sea bed, volcanic eruption above and under water, landslides or meteorite impacts. About 86 % of all Tsunamis result from so-called seaquakes.

In order for a tsunami caused by a seaquakes to occur, three things have to be happen:

1. The Earthquake must measure at least 7.0 on the Richter scale. Only from this intensity upwards is there enough energy released to rapidly displace enough water to create the tsunami.
2. The sea bed must be lifted or lowered by the earthquake. If the sea bed is displaced sideward, no tsunami will occur.
3. The epicentre of the earthquake must be near to the coastal area.

Characteristics of Tsunami

The difference between tsunamis and normal waves or waves caused by strong wind is the extreme distances between wavelengths. This is the distance from one wave crest to the next wave crest, which can be between 100 and 300 km. A further feature of tsunamis is their relatively small wave height on the open sea - mostly between half a metre and one meter. Even though they can travel up to 1000 km/h, these waves are generally not noticeable in deep waters. The wave itself only becomes dangerous once it reaches land.

In coastal areas where water levels gradually become shallower, the wave will slow down but tower into a wave wall as much as 30 meters high. The reason for this is the mass of water and energy contained in the tsunami wave. Whereas only the upper water layers are being moved in wind created waves, with a Tsunami wave, an entire mass of water from the sea bed to the surface is in motion.

If a trough of a tsunami wave approaches the land first, the water will be pulled back into the sea by enormous currents. Vast stretches of the seabed are often drained. In this case, and if recognised, people on the beach and beachfronts have between a few minutes and half an hour to escape to higher ground. The time to escape depends on when the wave crest strikes.

The first wave, that can grow to be up to 30 meters high at the beach, will usually be followed by more waves that are sometimes even more dangerous. Not only the crests of waves are dangerous but also the troughs, since their currents can pull people and whole houses many miles into the sea.

Effects of Tsunami

Tsunamis can cause great loss of life.

1. Shipwrecks can be left ashore when tsunamis hit. This can cause major pollution and can take time and money to remove.
2. Animals can be washed up to shore and die.
3. They can also flood the lands near the shore. This leaves crops damaged and the community can suffer from a lack of food and work.
4. Some people might left be trapped under buildings for long periods of time while search and rescue teams attempt to get a hold on the situation. The damage can be so great that people often die while trapped.
5. Tsunamis can cause economic decline as people have to spend a lot of money rebuilding the houses and restoring the original landscape. As the devastation can occur in very poor countries, there is usually not be enough help or money to completely rebuild entire livelihoods.

Management of Tsunami

Tsunamis are rare and difficult to predict. Although scientists can rapidly detect an undersea earthquake through the use of seismographs, not all undersea earthquakes will generate a tsunami. Other factors, such as the topography of the ocean floor at the epicentre of a quake, are involved. The early warning system is installed by some countries. Tsunami warnings are issued via radio, television, telephone, text message, etc. by national meteorological bodies of these countries.

AVALANCHE

An avalanche is a sudden and often rapid mass movement of snow and ice down a mountainside due to gravity. The word avalanche was derived from the French word *avalance* meaning descent.

Types of Avalanches

There are two main types to be concerned about: loose snow and slab avalanches.

A **loose snow avalanche** is simply loose snow that originates at a single point on a slope and gathers cohesion less snow on the surface of the pack as it descends. Loose snow avalanches often appear as an inverted 'V" pattern on the snow slope. They are capable of burying a person or carrying someone over a cliff but rarely are large enough to do significant property damage.

A **slab avalanche** occurs when a cohesive layer of snow slides down a slope. Since slab avalanches often form from new snow and wind, they are referred to as "wind slabs."

Causes of Avalanches

Causes of avalanches can be classified into major four categories:

Terrain-related factors.

- Factors contributing to avalanche formation are slope angle, slope size, slope shape, aspect with respect to wind, vegetation & terrain.

Snowpack related factors

- Layers of snow build-up and slide down the mountain at a faster rate on steep slopes.

- Snow pack stability is another factor. If snow with large & weak crystal structures fall onto a layer that is more cohesive the slope becomes more vulnerable to Avalanche.

Weather-related factors

- Heavy snowfall is the first, since it deposits snow in unstable areas and puts pressure on the snowpack.
- Heavy snowstorms are more likely to cause avalanches. The 24 hours after a storm are considered to be the most critical.
- Precipitation during the summer months is the leading cause of wet snow avalanches.

Man-related factors.

- Humans have contributed to the start of many avalanches in recent years. Winter sports that require steep slopes often put pressure on the snowpack which it cannot deal.
- The heavy deforestation and soil erosion in mountain regions, gives the snow little stability in the winter months.
- The use of vehicles and snowmobiles creates vibrations within the snow that it cannot withstand.
- The construction work done with explosives tend to weaken the entire surrounding area.

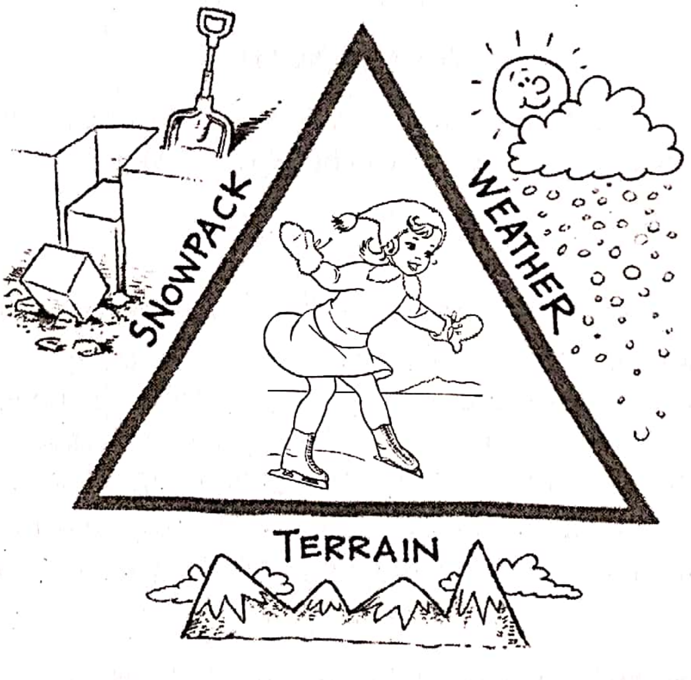


Figure: Elements of Avalanches

Effects of Avalanches

Loss of Life: A large number of casualties take place after avalanches hit heavily-populated areas. In April 2012, a deadly avalanche engulfed Pakistan Army headquarters near the Siachen Glacier in the eastern Karakoram Range in the Himalayas. More than 130 people buried due to the incident and most of them were Pakistani soldiers.

Loss of Property: Infrastructure is damaged and the blockage caused, impacts the livelihood of many. People who enjoy skiing, snowboarding and snowmobiling are at a greater risk of losing their lives. A powerful avalanche can even destroy buildings and power supplies can be cut off.

Traffic blockage and road damage: Snow deposited on road surface can block traffic. Roads are damaged by avalanches. Road structures, such as retaining walls, overturned.

Flash Floods: When an avalanche occurs, it brings down all the debris with it and can cause havoc in low-lying areas.

Impact on Tourism: Various ski resorts depend on tourists to run their business successfully. Ski resorts, transportation routes and other businesses are forced to close until the avalanche decreases and weather conditions become suitable.

Loss of Flora and Fauna: Avalanche can damage the vegetation and destroy habitat of wildlife.

Management of Avalanche

Where avalanches ~~are~~ going to occur is hard to predict. Historical data, weather information and information about the actual snow on the mountainside is collected together to try and forecast the likelihood of an avalanche. Similarly, prediction of avalanche is not possible. Following steps shall taken for avalanche management:

Land use planning: Land can be grouped into red, orange, yellow and green areas. The red areas are considered too dangerous to be built on. The orange areas can be built on with restrictions, such as reinforcing buildings. Roads and railways can be protected by tunnels over them in the areas where an avalanche path is likely to travel.

Avalanche hazard, vulnerability, and risk assessment: This includes delineating areas susceptible to avalanche hazards for planning and decision-making purposes.

Research and development, Knowledge network and management: Establishing an effective system for gathering information on avalanche, loss assessment resulting from avalanches, and the effective dissemination of technical information and maps is an essential component of the disaster management process.

Capacity building and training: Developing institutional capacity and training for geoscientists, engineers, and planners is necessary for effective management of the avalanche hazard.

Public awareness and education: Effective communication of avalanche hazard issues to the affected communities through education, public awareness programmes, posters, audio-visual aids, media campaigns, etc., is required.

Afforestation: Lastly, trees can be planted, increasing stability of the slope and helping to reduce the damage further down the valley.

FLOODS

Flood is a high-water stage in which water overflows its natural or artificial banks onto normally dry land, such as a river inundating its floodplain.

Causes of Flooding

Meteorological Cause: Most floods caused by meteorological phenomena such as:

- Prolonged and intense rainfall
- Cyclones
- Typhoons, storms and tidal surges

Hydrological Cause: Flooding can also be caused by increased run off due to:

- Ice and snow melt
- Impermeable surfaces
- Saturated land
- Poor infiltration rates
- Land erosion

Anthropogenic Cause: Mankind plays a very important role in the magnitude and frequency of floods in many different ways. Actually, it is the human activities in water catchments which drastically intensify floods. These Include:

- Population growth
- Land use change, deforestation, and intensive agriculture
- Socio-economic and development activities
- Urbanization
- Climate change
- Global Warming

Effects of Floods

Floods can have devastating consequences and can have effects on the economy, environment and people. Typical effects from flood are classified into three types, primary effects , secondary effects and tertiary (long-term) effects

Primary Effects

Physical Damages: Physical damages include destruction and damage of property, bridges, buildings, sewer systems, roads and railway lines.

Casualties: People and livestock die due to drowning. It can also lead to epidemics and water-borne diseases.

Loss of resources: Impact on buildings and machineries, agriculture, vegetation, etc. and loss of millions of rupees that affects economy and GDP.

Secondary Effects

Landslides: Landslides are a major threat each year to human settlements and infrastructure and cause more property settlements and infrastructure, and cause more property loss. Landslide occurs as a result of changes in water contents, removal of lateral support by erosion and rise in ground water levels.

Soil erosion and Land degradation: Soil erosion removes valuable top soil which is the most productive part of the soil profile. This results in lower yields and higher costs of production.

Effects on Health: Direct health effects occur during the flood itself and are caused by the flood water. For example, injuries, heart attacks and mortality from drowning. While indirect effects include epidemic diseases, poisoning, post-traumatic stress disorder and unhygienic conditions.

Sedimentation: Sediment in river channels leading to reducing the channel capacity.

Communication infrastructure: Flooding has shut the roads, rail and other commination networks, and affected traffic and travel in and out of the region. Schools, colleges and universities also closed due to this problem.

Water Pollution: Water pollution is the contamination of water bodies. Clean drinking water becomes scarce (e.g. lakes, rivers, oceans, ground water). Water pollution affects plants and organisms living in these bodies of water and in almost all cases the effect is damaging either to individual species and populations, but also to the natural biological communities.

Tertiary or Long-term effects

It usually takes years for affected communities to be rebuilt and business to come back to normalcy. Long-term effects of flooding include economic hardship, rebuilding costs, food shortages, poverty, loss of production and provision of services, loss of economic growth and delay in development programmes.

Flood Prevention

Monitoring: Flood control starts with information. Government must install sensor networks in dikes that provide real-time information about behaviour and the potential failure site. Use satellites that permanently monitor the flooding in large areas.

Forecasting: Flood control integrates all the information into a single whole - by means of smart links between dependable systems. This makes forecasting systems more reliable. Meteorology, hydrology, geo-technology and crisis management traditionally function independently of one another. Linking these fields of work substantially increases reliability. Greatly improved forecasts can therefore be made of what may occur and the likelihood of it happening.

Management of Floods

Steps can be taken to manage flooding. Often these steps involve trying to lengthen the amount of time it takes for water to reach the river channel, thereby increasing the lag time. Flood management techniques can be divided into structural and non structural soft-engineering options. Structural or **Hard options** tend to be more expensive and have a greater impact on the river and the surrounding landscape. **Non structural** or **soft options** are more ecologically sensitive.

Structural Measures

Construction of Dam: Dams are often built along the course of a river in order to control the amount of discharge. Water is held back by the dam and released in a controlled way. This controls flooding. But building a dam can be very expensive. Water is usually stored in a reservoir behind the dam. This water can then be used to generate hydroelectric power or for recreation purposes.

River engineering: The river channel may be widened or deepened allowing it to carry more water. A river channel may be straightened so that water can travel faster along the course. The channel course of the river can also be altered, diverting floodwaters away from settlements.

But altering the river channel may lead to a greater risk of flooding downstream, as the water is carried there faster.

Non-structural Measures

Afforestation: Trees are planted near to the river. This means greater interception of rainwater and lower river discharge. This is a relatively low cost option, which enhances the environmental quality of the drainage basin.

Managed flooding (also called ecological flooding): River is allowed to flood naturally in places, to prevent flooding in other areas - for example, near settlements.

Urban Planning: Local authorities and the national government introduce policies to control urban development close to or on the floodplain. This reduces the chance of flooding and the risk of damage to property. There can be resistance to development restrictions in areas where there is a shortage of housing.

Awareness: In many developing countries, drainage systems are chocked with litter and people have little knowledge of the effects that can have during a rain. When it rains, waterways and culverts are blocked by massive chunks of litter and debris, and water finds its way into the streets and into people's homes. Education is therefore very important to inform and caution people on the dangers of floods, what causes floods, and what can be done to minimise its impact.

DROUGHT

Drought is defined as a deficiency of rainfall over an extended period – a season, a year or several years – relative to the statistical multi-year average for the region resulting in prolonged shortages in its water supply.

Causes of Drought

Lack of Rainfall (or precipitation): Droughts can occur when there is lack of 'expected' precipitation (rain and snow). Note that we say 'expected' because lack of rain alone does not mean a drought. Some regions can go for months without any rain, and that would be 'normal' for them. Farmers plant in anticipation of rains and so when the rains do not come, and irrigation infrastructure is absent, agricultural drought occurs.

Dry seasons: Within the tropics, distinct, wet and dry seasons emerge due to the movement of the Intertropical Convergence Zone or Monsoon trough. The dry season greatly increases drought occurrence, and is characterized by its low humidity, with watering holes and rivers drying up.

Surface Water Flow: Some regions are also well distributed with surface water (streams and rivers) that have their sources from far away mountains and watersheds. These surface waters may dry out if the flow from their sources upstream is affected. Hydro-electric dams and irrigation systems are some of the economic activities that can reduce the amount of water flowing to other areas downstream.

Deforestation: Vegetation play a key role in the water cycle, as they help reduce evaporation, store water and also contribute to atmospheric moisture in the form of transpiration. This means, cutting down trees (deforestation) in the name of economics, will expose surface water to more evaporation. It will also reduce the ability of the ground to hold water and make it easier for desertification to occur. It can set off drying conditions, especially for smaller water bodies. Cutting down trees is known to reduce a forest's watershed potential.

Global Warming and Climate Change: It is on record that human actions have contributed to more greenhouse gases in the atmosphere. As a result, there are warmer temperatures, often resulting in more dryness and bush fires. These conditions also tend to speed up drought conditions. The Global Climate Risk Index (CRI) developed by Germanwatch analyses the quantified impacts of extreme weather events and Pakistan has been identified as the tenth most affected and vulnerable country in the world, in 2015.

Mismanagement of resources: Pakistan needs a minimum storage capacity of 40% of the around 115 million acre-feet of water available in the Indus river system throughout the year. But the country's storage capacity is only 7% and is decreasing due to sediment build-up in reservoirs. This gives Pakistan a stored water supply, adequate to meet its needs, of just 30 days.

In contrast to, "carryover capacity" in other countries ranges from 200 days in India to 1,000 days in Egypt. In December 2015, the World Resources Institute ranked Pakistan among the 36th most water-stressed country in the world. Per capita water availability in Pakistan decreased to 1,032 cubic metres in 2016 from 5260 cubic metres in 1951 due to rapid growth in population and depleting water storage capacity of the reservoirs. Critical limit is 1,000 cubic metres per person per annum.

Effects of Drought

Water is involved in every part of human life and also for plants and animals. There are so many ways that water affects us both directly and indirectly. Common consequences of drought include:

1. Diminished crop growth or yield and carrying capacity for livestock.
2. Food shortage and famine due to lack of water for irrigation.
3. Habitat damage, affecting both terrestrial and aquatic wildlife.
4. Malnutrition, dehydration and related diseases.
5. Mass migration, resulting in internal displacement and international refugee crisis.
6. Desertification and wildlife migration.
7. Social unrest and conflict over natural resources, including water and food.
8. Wildfires and bushfires are more common during times of drought.
9. Death of people and animals.
10. Loss to economy.

Management of Droughts

Strategies for drought protection, mitigation or relief include:

Dams: Many dams and their associated reservoirs supply additional water in times of drought. Government can built mini and micro dams to conserve rain water for desert areas and dry mountainous areas.

Desalination: Desalination of sea water for irrigation or consumption nearby coastal areas is a good solution.

Drought monitoring: Continuous observation of rainfall levels and comparisons with current usage levels can help prevent man-made drought.

Land use planning: Carefully planned crop rotation can help to minimize erosion and allow farmers to plant less water-dependent crops in drier years.

Outdoor water-use restriction: Regulating the use of sprinklers, hoses or buckets on outdoor plants, filling pools, and other water-intensive home maintenance tasks.

Rainwater harvesting: Collection and storage of rainwater from roofs or other suitable catchments.

Recycled water: Former wastewater (sewage) that has been treated and purified for reuse.

Redirecting rivers: Building canals or redirecting rivers as massive attempts at irrigation in drought-prone areas.

Cloud seeding: A form of intentional weather modification to induce rainfall.

Water Conservation: Serious conservation steps need to be taken to improve the efficiency of water use in Pakistani agriculture which claims almost all of the available fresh water resources. Rather than flood irrigation method currently used in Pakistani agriculture, there is a need to explore the use of drip or sprinkler irrigation to make better use of nation's scarce water resources before it is too late.

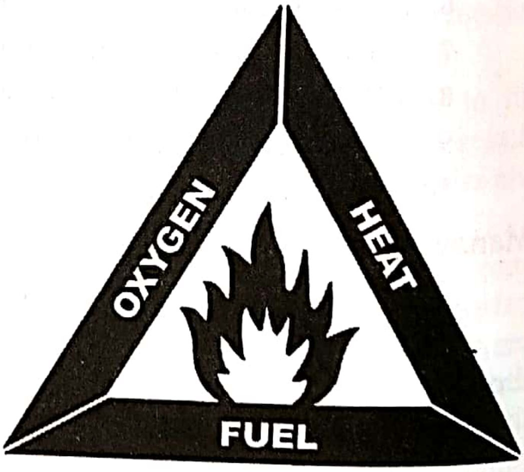
WILDFIRE AND URBAN FIRE

Fire is the visible part of combustion. Combustion is a chemical reaction of three things: ***heat, fuel and oxygen***. These three ingredients must be present before a fire can be made and maintained. This can be best explained in the fire triangle. For the fire triangle to stand, all three ingredients must be present. If the heat is not enough, or the fuel runs out, or the oxygen runs out, the fire will be out. A **wildfire** is simply an uncontrolled fire that is wiping out large fields and areas of land. Wildfire can wipe out an entire forest and destroy almost every organic matter in it. Wildfires can also be termed *forest fires, grass fires, peat fires and bush fires* depending on type of vegetation being burnt.

Causes of Wildfire

Below are the most common ways in which wildfires are started.

- Campfires
- Smoking
- Lightening
- Burning debris
- Accidents or equipment failure
- Fireworks
- Dry weather
- Arson



Effects of Wildfires

Loss of Flora and Fauna: Wildfire cause an immediate and severe damage to wildlife and vegetation. Fires also destroy houses and almost anything in its way. Governments spend millions of rupees to fight them with chemicals, logistics, aircraft and trucks, time and personnel.

Loss to Economy: Economic costs range from direct costs associated with fire fighting, to loss of income from the land following wildfire incidents and damage to property. Landscape-scale damage and loss of specific infrastructure can also impinge on tourism, with a consequence to local businesses and communities. Restoring damaged habitats is also becoming an important component of post-wildfire recovery in sensitive environments, which is typically a very costly and time-consuming process.

Loss of Soils and Organic Matter: Forest soils are rich in decaying debris and nutrients, and are composed of many natural features that support a myriad of life forms and organic activities. Wildfires raise the temperatures of these soils to over 900°C and this potentially wipes away almost all the organic value of the soil.

Watershed and Erosion: Burned organic matter in the soil also affects the natural layering of the soils. This negatively affects infiltration and percolation, making the soil surfaces water repellent. Water therefore is unable to drain into water tables and the run-offs on the surfaces cause erosion. The disruption and imbalance of the water distribution and flow can also cause floods in areas where normally this would not occur.

Air Pollution: Wildfires pollute the air with emissions harmful to human health. Fire also releases carbon dioxide — a key greenhouse gas — into the atmosphere. These fires also create heavy smog that is harmful to human and animal life. Apart from the obvious effects of wildfires on biodiversity and habitats, they also have a direct impact on benefits that people receive from the environment, including:

- Provision of food, water and fibre
- Regulation of floods, drought, land degradation and disease
- Cultural services and recreational benefits

The Positive Consequences of Wildfires

Wildfires can serve to clean up any dead or decaying matter strewn across forest, which, in turn, enables an increase in new plant growth. Wildfires are also useful in maintaining the balance within an ecosystem by removing any harmful insects and diseased plants. An added benefit of plant removal is an increase in sunlight, which can assist in the regeneration of plant seeds. Scientists have also realized that wildfires can increase the amount of plant and animal diversity within a particular ecosystem. In the midst of a wildfire, exceptional amount of nutrients are released into the soil, which can result in a flood of new plant growth. Some plants even require wildfires to germinate their seeds and stimulate growth, such as some species of pine.

Wildfire Management

Different fires are fought differently, but the big idea is usually the same to deprive the fire of its fuel and let it go out by itself. This can be achieved in many ways.

Fire Lines or Fire Breaks: With bulldozers and land equipment, fire-fighters clear a ring around the fire area and to get rid of all fuel in the fire's path. As the fire gets to the ring, it can no longer spread as there is no fuel in its path.

Firing Out: Fire-fighters look for a natural edge or boundary, such as a road, stream or plain field, and they do a controlled burn of all the fuel between the barrier and the fire. This means that before the fire gets there, it would have already burned out.

Air Tankers: Special aircraft call air tankers fly over the fire and dump water, fire retardant and chemicals (foam) on the fire. An example of such chemical is ammonium phosphate. Sometimes suspended buckets of between 100 to 2000 gallons carry water and sprinkle it over the fires.

Use of Remote Sensing and GIS: These days, satellites, computers, aircraft and digital equipment are used to monitor fires, forecast wind directions and create instant and effective maps and information needed to fight fires. This makes it a lot easier and quicker for fire-fighters to contain and put out fires.

Fire-Fighters: Trained fire-fighters are key to fighting fires. They get into gear (wear oxygen masks, appropriate fireproof clothing) and carry important tools on them to fight fires. Sometimes they also carry fire shelters if they get close to fires. There are special tents protect them from extreme heat in case they are trapped by the fires.

URBAN FIRE

A structure fire is a fire involving the structural components of various types of residential, commercial or industrial buildings. It is also termed as urban fire or house fire.

Causes of Urban Fire

Here are the most common causes of Urban Fire.

- Cooking equipment and kitchens
- Heating equipment and home heating failure
- Careless smoking in bed
- Electrical equipment failure
- Candles
- Children playing with fire
- Inadequate and faulty wiring
- Flammable liquids
- Barbecues

Firefighting and Fire control

Fire fighting is the act of extinguishing fires. A fire-fighter suppresses and extinguishes fires to protect lives and prevent the destruction of property and the environment. Following guidelines shall be followed during fire fighting and fire control:

Rescue: Human life is the most important consideration at a fire or other emergency. A primary and secondary search shall be conducted at all structure fires.

Exposure protection: Second strep is exposure protection. Exposure protection is a tactic used to prevent a fire from spreading to an uninvolved building or buildings.

Confinement: Tactics used to keep the fire from spreading in the building of origin. These may be offensive or defensive in nature.

Extinguishment: At some point a thorough overhaul of the affected area must be performed to insure total extinguishment of the fire.

Overhaul: Tactics used to open all void or hidden spaces where fire might hide from extinguishment efforts. Overhaul should be performed by fresh crews if possible to reduce the chance of fatigue-related injuries.

Ventilation: Tactics employed to remove smoke and super-heated gases from the fire building.

Salvage: Salvage tactics may include:

- Removing water from structure
- Covering property with salvage covers
- Removing property from fire building

Utility Control: Following steps may be taken

- Shut off gas supply if possible
- Shut off electric supply from the main breaker at the panel if possible

TROPICAL CYCLONE

Monsters from the tropics

Tropical storms, cyclones, hurricanes and typhoons, although named differently, describe the same disaster type. Essentially, these disaster types refer to a large scale closed circulation system in the atmosphere which combines low pressure and strong winds that rotate counter clockwise in the northern hemisphere and clockwise in the southern hemisphere. In meteorology, a tropical cyclone is a type of low-pressure system which generally forms in the tropics.

What is the difference between "hurricane", "cyclone" and "typhoon"?

"Tropical cyclone" is the general name for a kind of storm, while "typhoon" and "hurricane" are the names applied to these storms in particular locations. All tropical cyclones form over warm oceans and begin losing strength when they move over cool water or land.

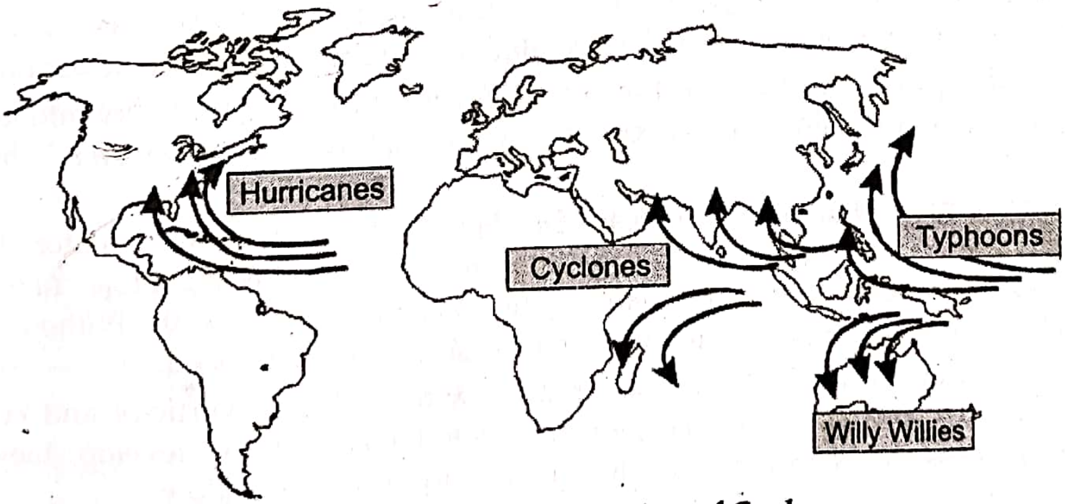


Figure: Geographical Distribution of Cyclones

- In the East and west of USA such a weather phenomenon is called "hurricane".
- In the western North Pacific near Japan, it is called "typhoons".
- Elsewhere, these storms are just called tropical cyclones or cyclones.

Formation of Tropical Cyclones

All storms (including thunderstorms, tropical cyclones, extratropical cyclones and tornados) have two things in common: low atmospheric pressure at the storm's centre, and winds that are created by the flow of air from higher pressure outside the storm toward the low pressure at the centre. Wind, in other words, is air that's being pushed by high pressure toward low pressure.

Areas of low air pressure occur because the Sun heats the Earth unequally. The Sun shines down almost directly on Earth's tropical regions near the equator, heating this region more than the Polar Regions around the North and South poles and the middle latitudes between the poles and the tropics. Storms, along with ocean currents, redistribute heat from the tropics to the middle latitudes and the poles. Without storms and ocean currents, the tropics would grow hotter and hotter until the oceans boiled. In other words, the Sun's heat powers the weather.

Air pouring into an area of low pressure from all sides rises because it doesn't have any place else to go. As air rises, it cools, and if it cools enough the water vapour in the air begins to condense. This condensation creates the tiny drops of water or tiny ice crystals that make up clouds. Under the right conditions, the tiny water drops or ice crystals merge to fall from the cloud as larger water drops of rain or ice crystals of snow. This is why, storms bring clouds and usually bring rain, snow, or other kinds of ice.

Condition for formation of a tropical cyclone

Tropical cyclones produce sustained winds of 120 km/h (74 mph) and faster. In their earlier stages, when their winds range in speed from 63 to 119 km/h (39 to 73 mph), they are generally called tropical storms. To undergo tropical cyclogenesis, there are several favourable pre cursor environmental conditions that must be in place:

- Warm ocean waters (of at least 26.5°C [80°F]) throughout a sufficient depth.
- An atmosphere which cools fast enough with height such that it is potentially unstable to moist convection. It is the thunderstorm activity which allows the heat stored in the ocean waters to be liberated for the tropical cyclone development.
- Relatively moist layers near the mid-troposphere (5 km [3 mi]). Dry mid levels are not conducive for allowing the continuing development of widespread thunderstorm activity.
- A minimum distance of at least 500 km (300 mi) from the equator. For tropical cyclogenesis to occur, there is a requirement for non-negligible amounts of the Coriolis force to provide for near gradient wind balance to occur. Without the Coriolis force, the low pressure of the disturbance cannot be maintained.
- A pre-existing near-surface disturbance with sufficient vorticity and convergence. Tropical cyclones cannot be generated spontaneously. To develop, they require a weakly organized system with sizable spin and low level inflow.

- Low values (less than about 23 mph of vertical wind shear between the surface and the upper troposphere. Vertical wind shear is the magnitude of wind change with height. Large values of vertical wind shear disrupt the incipient tropical cyclone and can prevent genesis, or, if a tropical cyclone has already formed, large vertical shear can weaken or destroy the tropical cyclone by interfering with the organization of deep convection around the cyclone centre.

Having these conditions met is necessary, but not sufficient as many disturbances that appear to have favourable conditions do not develop.

Stages of Development

Tropical cyclones are classified in accordance with the World Meteorological Organization's recommendations by the maximum sustained wind speeds near the centre.

Tropical Disturbance: Winds weak and unorganized

Tropical Depression: Winds less than 39 mph

Tropical Storm: Winds 39 to 74 mph

Tropical Cyclone or Hurricane: Winds greater than 74 mph

Saffir-Simpson Hurricane Wind Scale

The Saffir-Simpson Hurricane Wind Scale is a 1 to 5 rating based on a hurricane's sustained wind speed. This scale estimates potential property damage. Hurricanes reaching Category 3 and higher are considered major hurricanes because of their potential for significant loss of life and damage. Category 1 and 2 storms are still dangerous, however, and require preventative measures.

Category	Sustained Winds	Types of Damage Due to Hurricane Winds
1	74-95 mph 119-153 km/h	**Very dangerous winds will produce some damage:** Well-constructed frame homes could have damage to roof, shingles, vinyl siding and gutters. Large branches of trees will snap and shallowly rooted trees may be toppled. Extensive damage to power lines and poles likely will result in power outages that could last a few to several days.
2	96-110 mph 154-177 km/h	**Extremely dangerous winds will cause extensive damage:** Well-constructed frame homes could sustain major roof and siding damage. Many shallowly rooted trees will be snapped or uprooted and block numerous roads. Near-total power loss is expected with outages that could last from several days to weeks.
3	111-129 mph 178-208 km/h	**Devastating damage will occur:** Well-built framed homes may incur major damage or removal of roof decking and gable ends. Many trees will be snapped or uprooted, blocking numerous roads. Electricity and water will be unavailable for several days to weeks after the storm passes.
4	130-156 mph 209-251 km/h	**Catastrophic damage will occur:** Well-built framed homes can sustain severe damage with loss of most of the roof structure and/or some exterior walls. Most trees will be snapped or uprooted and power poles downed. Fallen trees and power poles will isolate residential areas. Power outages will last weeks to possibly months. Most of the area will be uninhabitable for weeks or months.

5	157 mph or higher 252 km/h or higher	**Catastrophic damage will occur:** A high percentage of framed homes will be destroyed, with total roof failure and wall collapse. Fallen trees and power poles will isolate residential areas. Power outages will last for weeks to possibly months. Most of the area will be uninhabitable for weeks or months.

Who gives Hurricanes their Names?

Regional Specialized Meteorological Centres (RSMCs) working under the World Meteorological Organization (WMO) selects hurricane names, using alternating men's and women's names in alphabetical order in respective regional languages. Names of those cyclones that cause great damage are retired from the list. Otherwise, names remain on six rotating, yearly lists, with each list being used again six years after its last use. In 2012 the most devastating hurricane was called Sandy. It was a category 3 hurricane that made landfall in the eastern coast of the USA between the 22nd and 29th of October. It caused approximately 50 billion USD worth of damage and 147 deaths. For interest of students a sample of three lists of North Indian Ocean is reproduced below.

List of Northern Indian Ocean tropical cyclone names

List	Contributing nation							
	Bangladesh	**India**	**Maldives**	**Myanmar**	**Oman**	**Pakistan**	**Sri Lanka**	**Thailand**
1	Onil	Agni	Hibaru	Pyarr	Baaz	Fanoos	Mala	Mukda
2	Ogni	Akash	Gonu	Yemyin	Sidr	Nargis	Rashmi	Khai Muk
3	Nisha	Bijli	Aila	Phyan	Ward	Laila	Bandu	Phet

Effects of Hurricanes / Cyclones

The impact of a tropical cyclone and the expected damage depend not just on wind speed, but also on factors such as the moving speed, duration of strong wind and accumulated rainfall during and after landfall, sudden change of moving direction and intensity, the structure (e.g. size and intensity) of the tropical cyclone, as well as human response to tropical cyclone disasters.

Environmental Impacts

Storm surge: Hurricanes bring about storm surges. The powerful spiral wind action carries water a couple of feet high and lashes it ashore. This can destroy structures and items very close to the shore. Storm surges are the main causes of the floods they bring. This is a rise in the ocean's water level as a result of extreme winds blowing over the sea's surface. Water levels can rise up to 15 feet and a lot more. As the storm makes a landfall, the high sea level brings water inland, causing major flooding and destruction.

Floods: Hurricanes carry a lot of rains with it and even after the hurricane has subsided, it may continue to rain. This causes a lot of floods and brings about other types of destructive results.

Winds: Houses, cars, farms, and many other structures are blown away by the powerful winds that come with hurricanes.

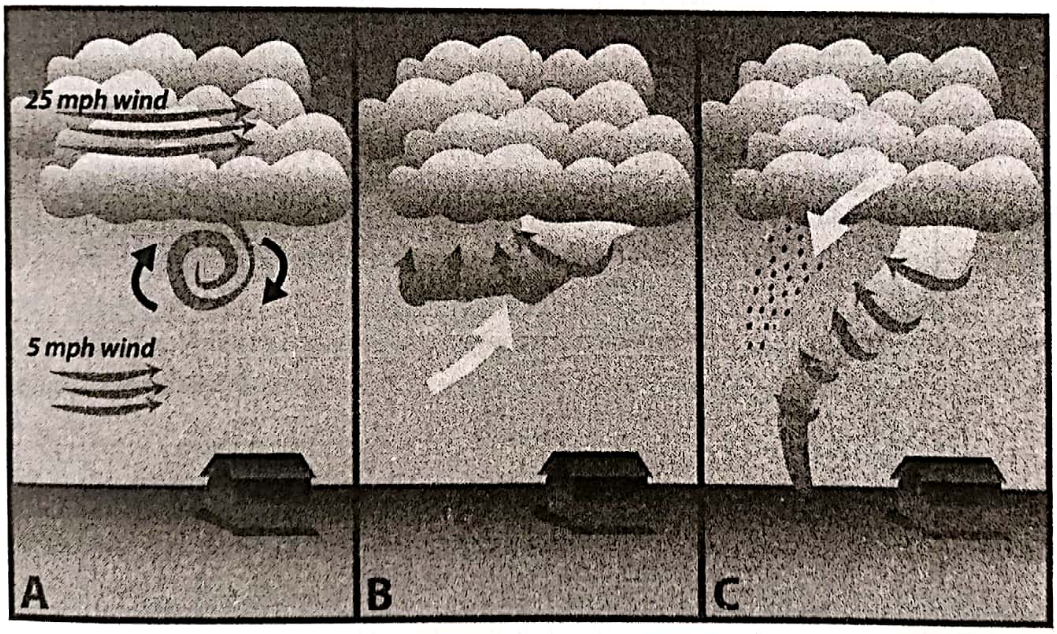
Tornadoes: This is probably the least thought of effect of a hurricane, but they do occur. Tornadoes occur in a hurricane as a result of the tremendous energy and instability created when a hurricane makes landfall. Most tornadoes that occur in hurricanes are only minimal in strength.

Socio-economic Impacts

Any time there is a disaster caused by a natural phenomenon like hurricanes, floods and fires, there is extensive damage to property. Peoples' livelihoods are wiped away and may take many years to get things together again. In many cases, there are fatalities and entire communities are severely affected. People may be forced to stay home for so long and businesses suffer as a result. In addition to that, the governments spend huge amounts of resources in preparation for these occurrences. Emergency work and rebuilding of infrastructure cost the city a lot of money. It is known that hurricane Sandy caused about US $ 50 billion worth of damage to the people of the United States of America.

TORNADO

A tornado, or twister, is a violently rotating column of air that extends between the Earth's surface and a cloud, usually a cumulonimbus cloud. Most tornadoes last for less than ten minutes. Large tornadoes usually last longer—around 30 minutes. The most powerful twisters have wind speeds of more than 300 miles (483 kilometers) per hour, which can rip buildings off their foundations. They can be more than two miles (3.2 kilometers) wide, and can spin across the ground for dozens of miles. The more common tornadoes have wind speeds of less than 110 miles (177 kilometers) per hour, are about 250 feet (76 meters) across, and travel only a few miles before they dissipate. Tornadoes kill an average of 60 people a year in the U.S., mostly from flying or falling debris. Half of those deaths are caused by the strongest one percent of the most violent storms



Tornado Formation

Tornadoes are simply borne out of supercell storms. A supercell storm is a thunderstorm characterized by powerful updrafts. The formation of a tornado follows a clear set of steps. First there is a change in wind direction and an increase in wind speed. This change occurs at an increasing altitude and creates an invisible horizontal spinning effect in the lower atmosphere. Winds at different altitudes blow at different speeds, creating wind shear. For example, a wind at

1000 feet above the surface might blow at a speed of 5 miles per hour and a wind above that, at 5000 feet, might blow at 25 miles per hour. A horizontal rotating column of air can form at the boundary between these two winds.

Next, rising air within the thunderstorm's updraft tilts the rotating air from horizontal to vertical. Third, an area of rotation, 3-10 km wide is contained within a vast majority of the storm. This is where the strongest tornadoes form. Then a lower cloud base in the center of the storm becomes a rotating wall cloud. This area can be nearly rain-free. Lastly, a tornado develops and starts to wreak its destruction.

Fujita Tornado Damage Scale

The Fujita scale (F-Scale), or Fujita–Pearson scale (FPP scale), is a scale for rating tornado intensity, based primarily on the damage tornadoes inflict on human-built structures and vegetation. These precise wind speed numbers are actually guesses and have never been scientifically verified. Different wind speeds may cause similar-looking damage from place to place -- even from building to building.

Scale	Estimated wind speed		Potential damage
	mph	km/h	
F0	40–72	64–116	**Light damage.** Some damage to chimneys; branches broken off trees; shallow-rooted trees pushed over; sign boards damaged.
F1	73–112	117–180	**Moderate damage.** The lower limit is the beginning of hurricane wind speed; peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off the roads; attached garages may be destroyed.
F2	113–157	181–253	**Significant damage.** Roofs torn off frame houses; mobile homes demolished; boxcars overturned; large trees snapped or uprooted; high rise windows broken and blown in; light-object missiles generated.
F3	158–206	254–332	**Severe damage.** Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted; heavy cars lifted off the ground and thrown.
F4	207–260	333–418	**Devastating damage.** Well-constructed houses leveled; structures with weak foundations blown away some distance; cars thrown and large missiles generated.
F5	261–318	419–512	**Incredible damage.** Strong frame houses lifted off foundations and carried considerable distances to disintegrate; automobile sized missiles fly through the air farther than 100 metres (330 ft); trees debarked; steel reinforced concrete structures badly damaged.

Effects of Tornadoes

Tornadoes are known to clock a speed of 70 - 80 mph - with the winds within them rotating at the speed of 200 miles at times. It is this speed that adds to the devastating power of tornadoes, as a result of which they cause destruction along their path. At such speed, it is very difficult to predict their future course of action, and before you realize what's happening these twisters just rip through the town leaving it in shambles.

Even though they are short-lived, tornadoes are nature's most violent and destructive atmospheric phenomenon. They are capable of toppling buildings, lifting and rolling homes and automobiles, and hurling people, animals, trees, and debris hundreds of yards in the air. The United States has the dubious distinction of having the most severe, damaging tornadoes of any country in the world. The fact is that most tornado-related deaths are caused by head injuries from flying debris. Sticks, glass, roofing materials, lawn furniture and other similar materials become deadly missiles when driven by the force of a tornado's strong winds.

Tornados typically have limited secondary effects. The most common is power failure, as severe wind conditions dismantle power sources. Significant structural damage to property, facilities, or infrastructure could cause small segments of the population to temporarily displace. Hazardous material spills can occur if a tornado damages a holding tank or causes a traffic accident. Limited disruptions of critical emergency services may be experienced by non-affected portions of an area. Economic and financial impact can range from nominal to major, based on the severity of damage. Then there are the psychological effects on people. Probably the biggest is PTSD (Post Traumatic Stress Disorder).

Tornadoes occur around the world but are most common in the so-called Tornado Alley of the Midwestern United States. Three-quarters of tornadoes around the world occur in the United States. Australia, New Zealand, Bangladesh and some parts of Africa and South America also experience significant tornado activity.

MIDLATITUDE CYCLONES

Probably most significant of all atmospheric disturbances are **Midlatitude cyclones.** Throughout the Midlatitude, they dominate weather maps, are basically responsible for most day-to-day weather changes, and bring precipitation to much of the populated portions of the planet. Consisting of large, migratory low-pressure systems, they are usually called *depressions* in Europe and sometimes referred to as lows *wave cyclones, or extratropical cyclones* in the United States.

Midlatitude cyclones are associated primarily with *air-mass* convergence and conflict in regions between about 30⁰ and 70⁰ of latitude. Thus, they are found almost entirely within the band of westerly winds. Their general path of movement is toward the east. To understand the Midlatitude phenomenon it is necessary to understand Air Masses and Fronts.

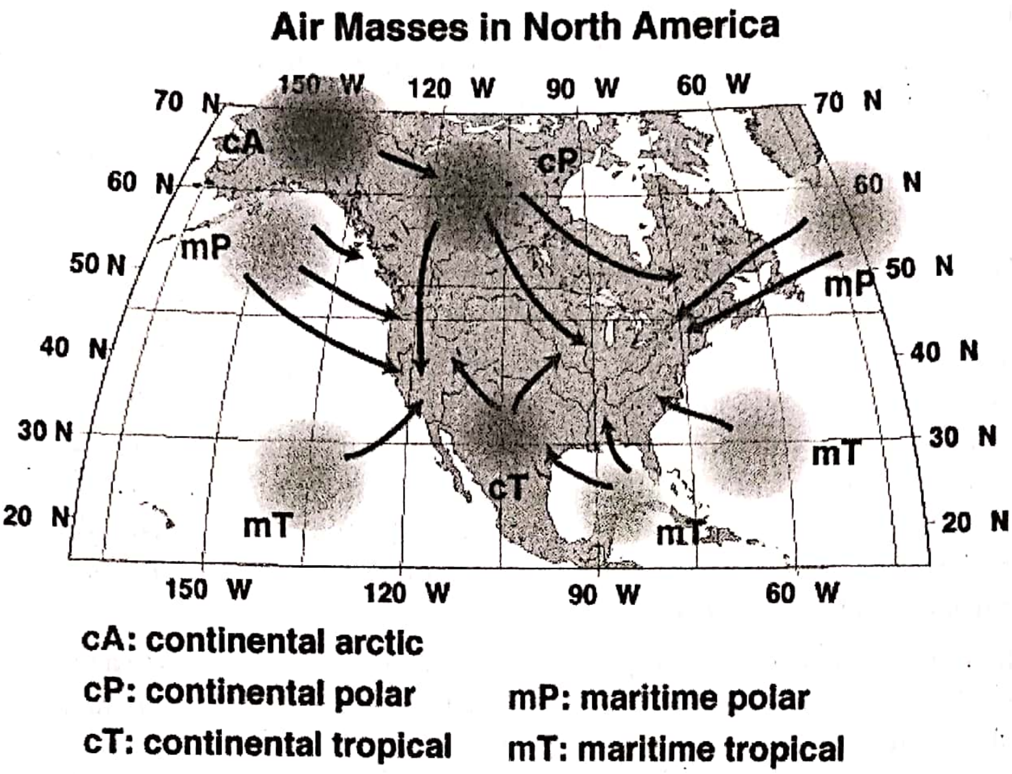
Air Masses

Air Mass is an extremely large body of air whose properties of temperature and moisture content (humidity), at any given altitude, are fairly similar in any horizontal direction.

Air mass can cover hundreds of thousands of square miles. Source regions are simply geographic areas where an air mass originates. Should be:

- uniform surface composition - flat
- light surface winds

The longer the air mass stays over its source region, the more likely it will acquire the properties of the surface below. Four general air mass classifications categorized according to the source region are:



- *polar latitudes* P - located poleward of 60 degrees north and south
- *tropical latitudes* T - located within about 25 degrees of the equator
- *continental* c - located over large land masses (dry)
- *marine* m - located over the oceans (moist)

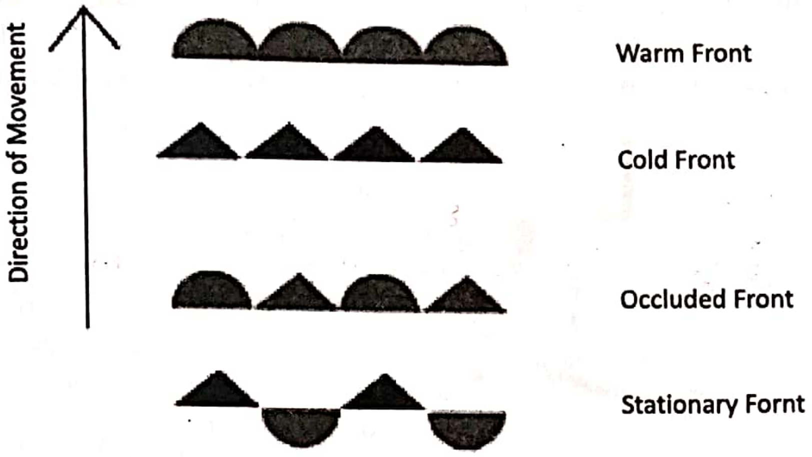
We can then make combinations of the above to describe various types of air masses.

- cP-continental polar (cold, dry, stable)
- cT-continental tropical (hot, dry, stable air aloft--unstable surface air)
- mP-maritime polar (cool, moist, and unstable)
- mT-maritime tropical (warm, moist, usually unstable)

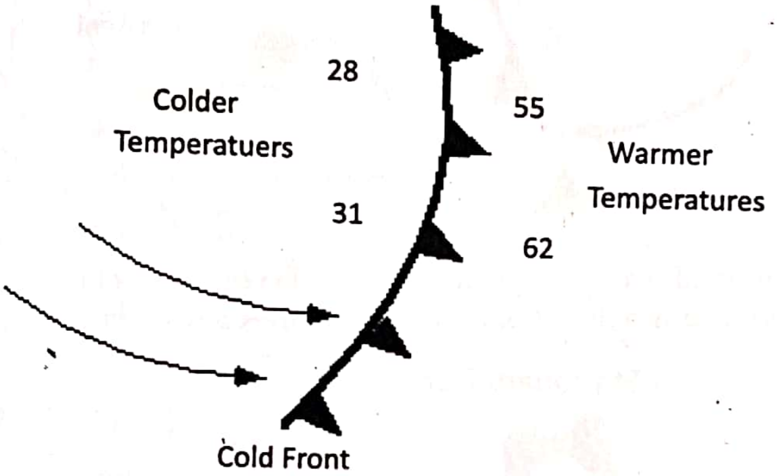
Fronts

Front is the transition zone between air masses with distinctly different properties. The differences in density are most often caused by temperature differences. The type of front depends on both the direction in which the air mass is moving and the characteristics of the air mass. There are four types of fronts cold front, warm front, stationary front, and occluded front.

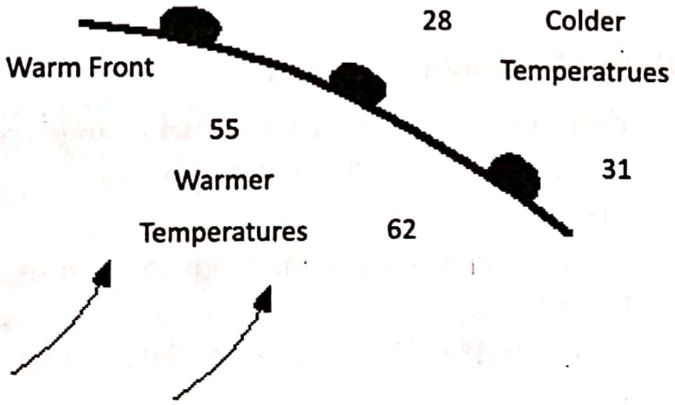
Meteorologists use both symbols and color to distinguish between synoptic scale fronts on weather maps. If printed in color, warm fronts are shown as a line of red semi-circles pointing in the direction of movement. Cold fronts are depicted as a line of blue triangles. Occluded fronts appear in purple with both warm and cold front symbols on the same side. The symbols point in the direction of the front is moving. Stationary fronts are alternating warm and cold front symbols on opposite sides, indicating no movement.



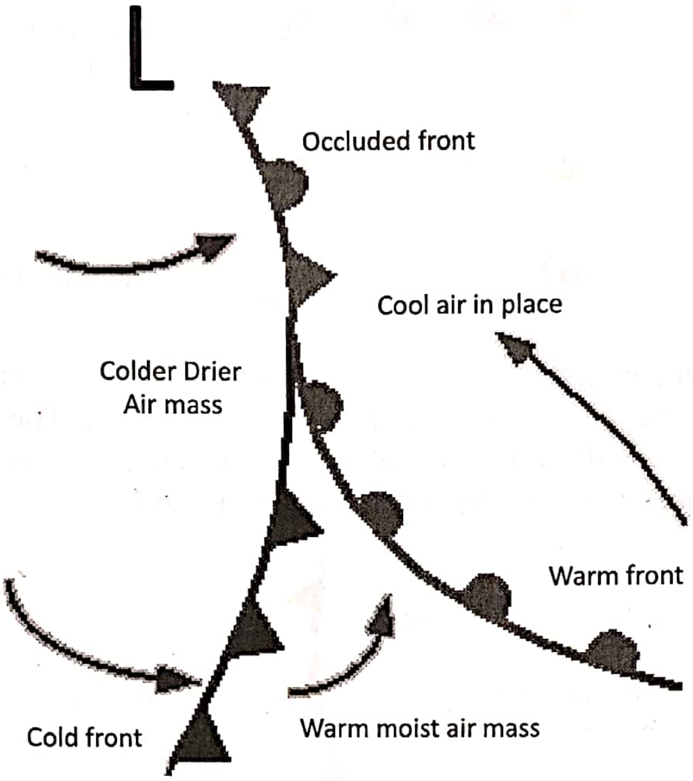
A **cold front** is defined as the transition zone where a cold air mass is replacing a warmer air mass. Cold fronts generally move from northwest to southeast. The air behind a cold front is noticeably colder and drier than the air ahead of it. When a cold front passes through, temperatures can drop more than 15 degrees within the first hour.



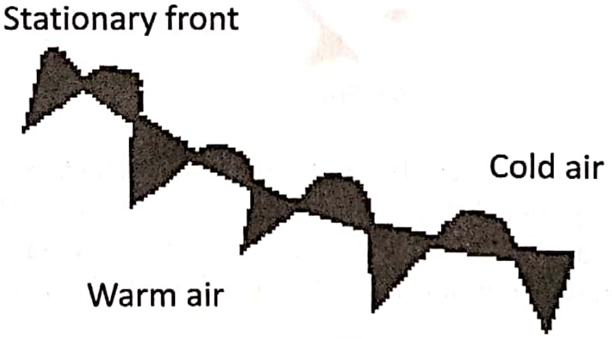
A **warm front** is defined as the transition zone where a warm air mass is replacing a cold air mass. Warm fronts generally move from southwest to northeast and the air behind a warm front is warmer and more moist than the air ahead of it. When a warm front passes through, the air becomes noticeably warmer and more humid than it was before.



As the storm intensifies, the cold front rotates around the storm and catches the warm front. This forms an **occluded front**, which is the boundary that separates the new cold air mass (to the west) from the older cool air mass already in place north of the warm front.



When a warm or cold front stops moving, it becomes a **stationary front.** Once this boundary resumes its forward motion, it once again becomes a warm front or cold front.



Weather Changes with the Passing of a Front

When a front passes through a region, abrupt weather changes normally occur. For example, with the passage of a cold front, we note the following:

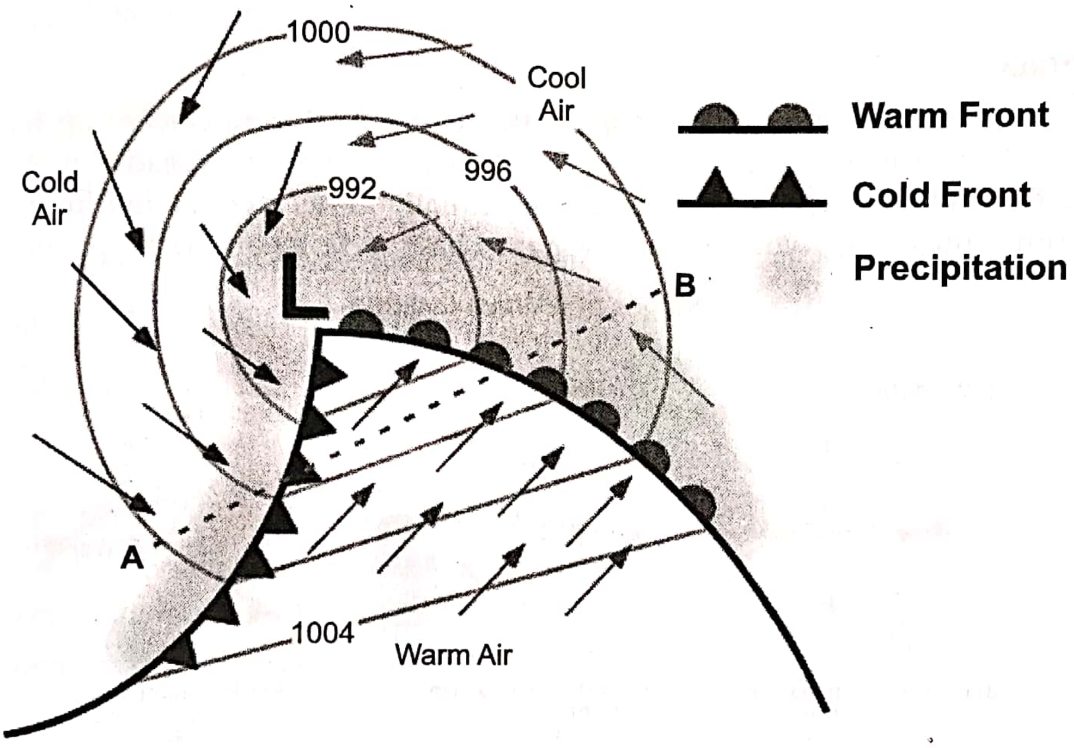
1. The temperature decreases sharply.
2. Winds shift from southerly ahead of the front to north-westerly following it (in the Northern Hemisphere).
3. The front is in a pressure trough, so pressure falls as the front approaches and rises after it passes.

4. Generally clear skies ahead of the front are replaced by cloudiness and precipitation at the front — to be replaced again by clear skies after the front moves away.

Similar changes, although of lesser magnitude, occur with the passage of a warm front.

Midlatitude Cyclone Characteristics

A developing cyclone is typically accompanied by a warm front pushing northward and a cold front pulling southward, marking the leading edges of air masses being wrapped around a center of low pressure, or the center of the cyclone. The counter clockwise winds associated with northern hemisphere midlatitude cyclones play a significant role in the movement air masses, transporting warm moist air northward ahead of a low while dragging colder, drier air southward behind it.



A typical mature midlatitude cyclone has a diameter of 1600 kilometres (1000 miles) or so. It is essentially a vast cell of low-pressure air, with ground-level pressure in the centre typically between 990 and 1000 millibars

Midlatitude Cyclone Life Cycle

Cyclogenesis

A typical midlatitude cyclone begin as "wave" (hence the alternative name wave cyclone) along the polar front, is the contact zone between the relatively cold air of the polar easterlies and the relatively warm air of the westerlies. The opposing airflows normally have a relatively smooth linear motion on either side of the polar front. On occasion, however, the smooth frontal surface may be distorted into a wave sharpe. Various ground factors — such as topographic irregularities, temperature contrasts between sea and land, or the influence of ocean currents — can apparently initiate a wave along the front, but it is believed that the most common cause of cyclogenesis (the birth of cyclones) is upper troposphere conditions in the vicinity of the polar front jet stream.

When an upper-level disturbance moves over the front, it causes a wave to form. Cyclonic shear begins to occur when the warm and cold fronts slide against one another, generating the spinning motion characteristic of cyclones. The meeting of cold and warm air creates precipitation, which is heaviest near the border of the front.

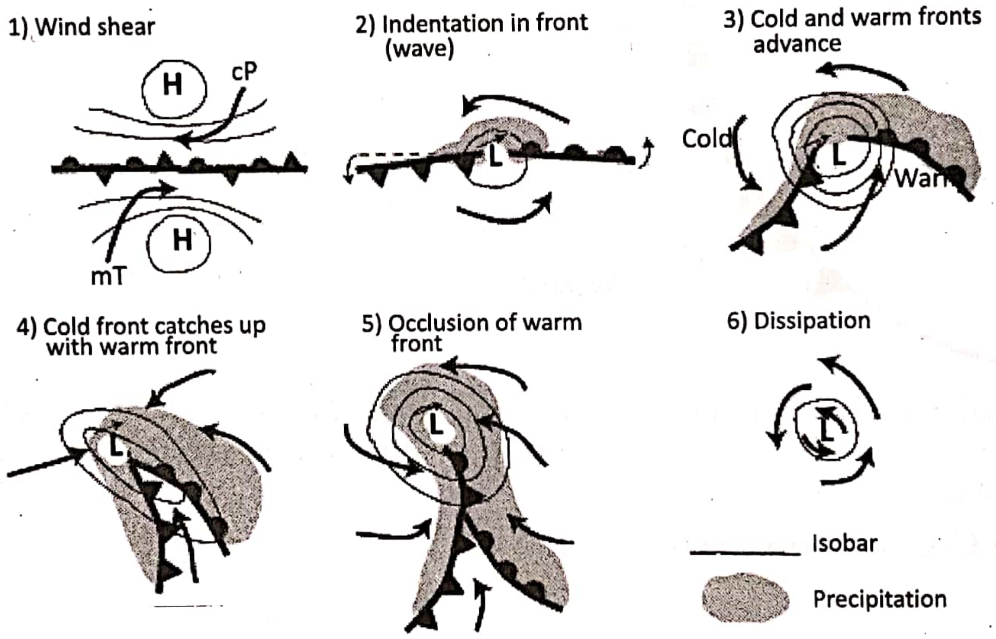
Mature Stage

During the cyclone's mature stage, the wave formed during the initial phase grows as warm air replaces the space left behind by the moving cold front, and the organization of both the cold and warm fronts increases. The cold front moves faster than the warm front, intensifying the cyclonic circulation. The system's lowest pressure is located at the center of the wave, and the cyclone's winds are strongest about eight miles above ground.

Occluded Stage

In the mid-latitude cyclone's third stage, the denser cold front catches up with the warm front. Because the warm air isn't dense enough to displace the cold air ahead of it, it shifts up and slides above the cold air in its path. This action eventually forms an occluded front, in which the wave transforms into a loop, which is narrower at its base and cuts off the supply of warm air.

Stages of a Wave Cyclone


1) Wind shear
H
cP
H
mT
2) Indentation in front (wave)
L
3) Cold and warm fronts advance
Cold
L
War
4) Cold front catches up with warm front
L
5) Occlusion of warm front
L
6) Dissipation
L
Isobar
Precipitation

Dissolving Stage

The final stage of the cyclone occurs when the loop formed by the cold front boundary surrounding the low-pressure pocket of warm air closes. This cuts off the supply of warm moist air and the lifting force caused by the interaction between the cold and warm fronts. The loss of the convergence and uplift mechanisms cause the cyclone to dissolve, and the low pressure system gradually stabilizes.

NATURAL HAZARDS & DISASTERS (MCQS)

Note: **Answers are Bold and Underlined:**

1. **Atmospheric pressure in the centre of a tropical cyclone is:**
(a) Very high because of converging winds
(b) Very high because of sinking warm air
(c) **Very low because of rising warm air**
(d) Very low because of dense sinking air

2. **A tropical storm becomes a hurricane and forms an "eye" when wind speeds exceed ________ miles per hour.**
(a) 10 (b) 39 (c) **74** (d) 96

3. **Which of the following factors are used to rate the intensity of a hurricane?**
(a) Barometric pressure (b) Wind speed
(c) Storm surge (d) **All of these**

4. **Most hurricanes in the Northern Hemisphere follow a track that moves:**
(a) **Northwest then northeast** (b) Northeast then northwest
(c) East (d) South

5. **In most hurricanes extensive death and destruction are caused mainly by:**
(a) Storm surge (b) Inland flooding
(c) Wind (d) **Both (a) and (b)**

6. **Which ocean does not commonly experience tropical cyclones?**
(a) North Atlantic (b) **South Atlantic** (c) Western Pacific (d) Indian Ocean

7. **Common ocean waves are primarily caused by:**
(a) Gravitational forces (b) Tides
(c) **Wind energy transferred to water** (d) Undersea earthquakes and volcanoes

8. **Heat transfer mechanisms associated with a burning log include:**
(a) Conduction (b) Convection (c) Radiation (d) **All of these**

9. **Which chemical reaction best represents the fire equation?**
(a) $6\,CO_2 + 6\,H_2O$ + solar radiation ---> $C_6H_{12}O_6 + 6\,O_2$
(b) **C6H12O6 + 6 O2 ----> 6 CO2 + 6 H2O + Released Heat**
(c) $Ca_2 + CO_3$ ----> $CaCO_3$
(d) $2\,SO_2 + O_2$ ---> $2\,SO_4$

10. **The process whereby wood degrades thermally, resulting in production of flammable hydrocarbons, is referred to as:**
(a) **Pyrolysis** (b) Diffusion (c) Katabatic (d) Paralysis

11. **The essential ingredients in any fire include:**
(a) Fuel source (b) Ignition (heat) (c) Oxygen (d) **a, b and c**

12. **The manner and rate at which fire spreads is a function of:**
(a) Topography (b) Wind direction and velocity
(c) Fuel source (d) **All of these**

13. **The chief role of drought in wildfires is:**
(a) **Drying out the fuel source**
(b) Making environmental conditions inhospitable for firefighters
(c) Igniting the fire
(d) Forcing the human population to withdraw from the area

14. **Which of the following might help prevent home fires?**
(a) Building on a slope.
(b) Building with stone or some other inflammable material.
(c) Clearing foliage away from the home.
(d) **Both (b) and (c)**

15. **A firestorm refers to:**
(a) A thunderstorm that generates an unusually high number of lightning strikes
(b) A swarm of fireflies descending on a summer party
(c) **An unusually hot and voracious wildfire often accompanied by fire tornadoes**
(d) A wildfire confined to the canopy of a hardwood forest

16. **Fire requires __________ to burn:**
(a) Oxygen (b) Fuel (c) Heat (d) **All of these**

17. **The largest wave during a tsunami event is:**
(a) The first (b) The third (c) The fifth
(d) **Unpredictable, it could be any of them**

18. **The destructive powers of tsunami result mainly from their:**
(a) Incredible height (b) Unpredictablility
(c) Cold water (d) **Momentum and long wavelength**

19. **In the open ocean, tsunami can travel ________ miles per hour with wave height upto feet.**
(a) 50; 20 (b) 100,60 (c) 485; 20 (d) **500; 100**

20. **Which event produces the biggest tsunami?**
(a) **Earthquake** (b) Underwater landslides
(c) Hurricanes (d) Tides & Currents

21. **Powerful tsunami are most frequently produced by:**
(a) Volcanoes (b) Underwater landslides
(c) **Earthquakes** (d) Impacts of asteroids

22. **Over 90% of volcanic activity is associated with:**
(a) Subduction zones (b) Transform boundaries
(c) Continent-continent collision zones (d) **Plate-tectonic boundaries**

23. **Hot spots under the continental lithosphere generally create __________ while those under oceanic lithosphere commonly create ____________ :**

(a) **Calderas; shield volcanoes**
(b) Shield volcanoes; stratovolcanoes
(c) Cinder cones; stratovolcanoes
(d) Calderas; stratovolcanoes

24. **The production of magma is favoured by an increase in ____________ and ___________, and a decrease in ___________.**

(a) Pressure; water content; heat
(b) **Pressure; heat; water content**
(c) heat; water content; pressure
(d) Solar heat; water content; pressure

25. **Weather and climate are driven by what source(s) of energy?**

(a) Earth's internal heat
(b) **Solar radiation**
(c) Gravity
(d) Both (a) and (c)

26. **The difference between weather and climate is:**

(a) Weather is a local phenomenon, climate is regional
(b) **Weather is a day-to-day phenomenon, climate is a long-term average**
(c) Weather is the non-scientific term for climate
(d) There is no difference between the two

27. **Warm air in the tropics rises because:**

(a) It has more energy
(b) Of the Coriolis Effect
(c) **It is less dense**
(d) It is more dense

28. **Cold air sinks because:**

(a) It has less energy
(b) Of the Coriolis Effect
(c) It is less dense
(d) **It is more dense**

29. **Air masses always move horizontally from:**

(a) **High pressure to low pressure areas**
(b) Low pressure to high pressure areas
(c) From oceans to continents
(d) From continents to oceans

30. **Air around low pressure zones (cyclones) in the Northern Hemisphere:**

(a) Spins clockwise
(b) **Spins counter clockwise**
(c) Spins sometimes clockwise, sometimes counter clockwise
(d) Moves directly towards the centre of low pressure

31. **Air around high pressure zones (anticyclones) in the Northern Hemisphere:**

(a) **Spins clockwise**
(b) Spins counter clockwise
(c) Spins sometimes clockwise, some times counter clockwise
(d) Moves directly towards the centre of low pressure

32. **A rapidly moving cold front that encounters warm moist air may produce:**

(a) **A narrow band of intense thunderstorms**
(b) A wide band of intense thunderstorms
(c) A wide band of intense rainfall without thunderstorms
(d) A wide band of moderate rainfall without thunderstorms

33. **A slowly moving warm front that encounters cooler air may produce:**
(a) A narrow band of intense thunderstorms
(b) A wide band of intense thunderstorms
(c) A wide band of intense rainfall without thunderstorms
(d) A wide band of moderate rainfall without thunderstorms

34. **The Fujita scale quantifies tornadoes, based on:**
(a) Length of time it is on the ground
(b) The extent of damages caused by wind
(c) Diameter of the funnel
(d) Speed at which the funnel moves across the ground

35. **A drought is defined as:**
(a) A desert region of low rainfall (b) A time of abnormally low rainfall
(c) A famine condition (d) A lack of water

36. **Which of the following does not promote mass movement?**
(a) Steep slopes (b) Forest fires
(c) Heavy rainfall (d) All of these

37. **A flash flood is a flood that:**
(a) Is caused by heavy rain rather than from the flooding of a river
(b) Occurs in urban areas
(c) Occurs suddenly and unexpectedly and for a short duration
(d) Is caused by the blocking of drains

38. **The level of a flood is measured by:**
(a) The rate of flow of water in a waterway or river
(b) The level of water in a waterway or river
(c) A river gauging station (d) All of these

39. **Which of the following is an environmental consequence of floods?**
(a) Dispersal of weed species (b) Erosion of soil
(c) Release of pollutants into waterways (d) All of these.

40. **Which of the following can reduce the risk of flooding?**
(a) Zonings and building regulations for new developments
(b) Dams, detention basins and levees
(c) Flood awareness and education programmes
(d) All of these.

41. **Volcanoes are generally found where _______ pull apart or are coming together.**
(a) Intraplates (b) Tectonic plates
(c) Earth's crust (d) None of these

42. **Which ridge has examples of volcanoes caused by "divergent tectonic plates" pulling a part?**

(a) Pacific ring of fire (b) **Mid Atlantic Ridge**
(c) Both (a) and (b) (d) None of these

43. **Which one has examples of volcanoes caused by 'convergent tectonic plate', coming together?**

(a) Mid Atlantic ridge (b) **Pacific ring of fire**
(c) Both (a) and (b) (d) None of these

44. **Volcanoes can also be caused by ______ so called 'hot spots'.**

(a) **Mantle plumes** (b) Ash
(c) Gases (d) None of these

45. **Volcanoes are usually located on:**

(a) Divergent plate boundaries (b) Convergent plate boundaries
(c) Hotspots (d) **All of these**

46. **A place where two plates usually an oceanic plate and a continental plate collides is called:**

(a) Continental zone (b) Volcanic zone (c) **Subduction zone** (d) None of these

47. **Volcanic erupted material when inside the hill/earth/mountain it is called ______ and after it coming out it is called ______.**

(a) Lava; magma (b) **Magma; lava** (c) Both (a) and (b) (d) None of these

48. **The volcanoes formed by the alternating layers of lava and rock fragments are called:**

(a) Cinder cones (b) Spatter cones
(c) **Composite volcanoes** (d) Shields

49. **The intensity of earthquakes is measured on**

(a) Richter scale (b) Secant scale
(c) **Mercalli scale** (d) Beaufort scale

50. **Which of the following is a mass movement?**

(a) Land slide (b) Avalanche
(c) Mudslide (d) **All of these**

CHAPTER 7

ATOMIC STRUCTURE AND CHEMICAL BONDING

Every substance is made up of chemical elements such as Carbon Hydrogen, Nitrogen Iron etc. These chemical elements cannot be broken down further into simpler substances by chemical means. A few elements, such as nitrogen and gold, are found on their own in nature, not combined with other elements. Most elements, however, are found in combination with other elements as compounds. A chemical element contain only one type of atoms. An **atom** is the smallest part of an element that can take part in a chemical change. Atoms are very small. The diameter of a hydrogen atom is approximately 10^{-10} m, so the mass of an atom must also be very small. A single hydrogen atom weighs only 1.67×10^{-27} kg.

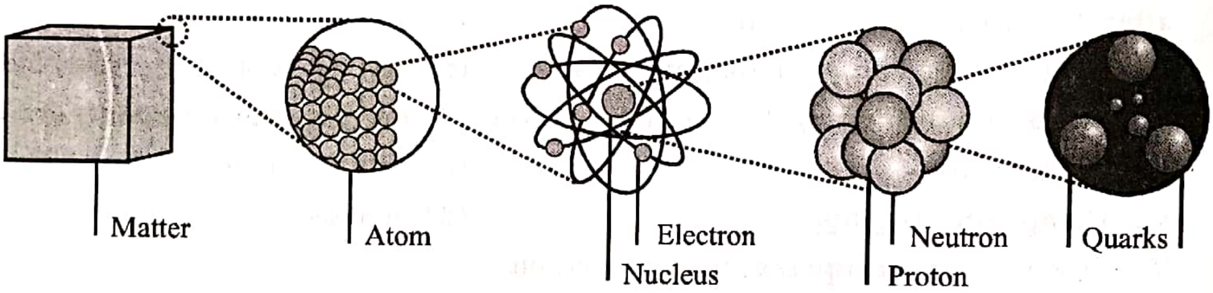


Figure: Atomic Structure

STRUCTURE OF ATOM

Every atom has nearly all of its mass concentrated in a tiny region in the centre of the atom called the nucleus. The nucleus is made up of particles called **nucleons**. There are two types of **nucleon:** *protons* and *neutrons*. Atoms of different elements have different numbers of protons. Outside the nucleus, particles called *electrons* move around in regions of space called orbitals. Chemists often find it convenient to use a model of the atom in which electrons move around the nucleus in electron shells. In a neutral atom, the number of electrons is equal to the number of protons. A simple model of a carbon atom is shown in figure.

Atoms are tiny, but the nucleus of an atom is far tinier still. If the diameter of an atom were the size of a football stadium, the nucleus would only be the size of a pea. This means that most of the atom is empty space! Electrons are even smaller than protons and neutrons.

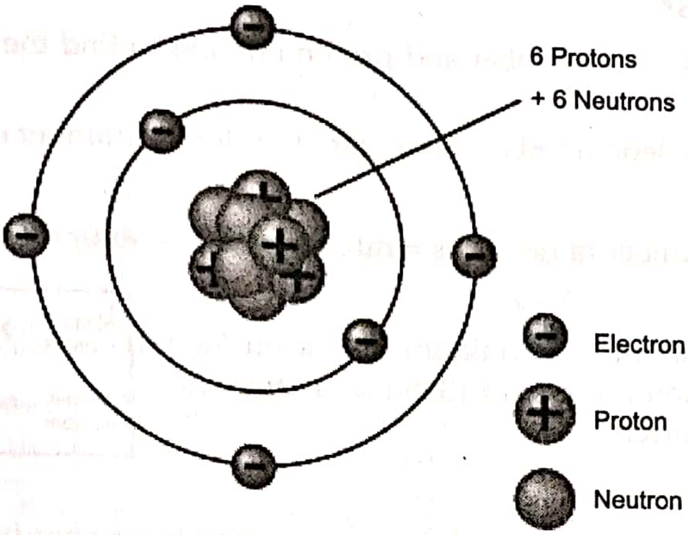


Figure: Structure of a Carbon Atom

Masses and Charges

Electrons, protons and neutrons have characteristic charges and masses. The values of these are too small to be very useful when discussing general chemical properties. For example, the charge on a single electron is -1.602×10^{-19} coulombs. We therefore compare, their masses and charges by using their relative charges and masses. These are shown in table below.

Particle	**Electron**	**Proton**	**Neutron**
Symbol	E	P	N
Nature	Negatively charged	Positively charged	Neutral
Relative charge	-1	+1	0
Absolute charge	1.6×10^{-19}c	1.6×10^{-19}c	0
Relative mass	1/1836 a.m.u	1 a.m.u	1 a.m.u
Absolute mass	9×10^{-24} g	1.6×10^{-24} g	1.6×10^{-24} g

Proton Number and Nucleon Number

The number of protons in the nucleus of an atom is called the **proton number (Z).** It is also known as the atomic number. Every atom of the same element has the same number of protons in its nucleus. It is the proton number that makes an atom what it is. For example, an atom with a proton number of 11 must be an atom of the element sodium. Atomic numbers of hydrogen, helium, lithium and carbon are 1, 2, 3 and 6, respectively. The Periodic Table of elements is arranged in order of the proton numbers of the individual elements

The **nucleon number (A)** is the number of protons plus neutrons in the nucleus of an atom. This is also known as the mass number. Mass numbers of hydrogen, helium, lithium and carbon are 1, 4, 6 and 12, respectively.

How Many Neutrons?

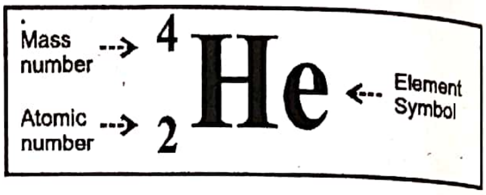
We can use the nucleon number and proton number to find the number of neutrons in an atom. As:

nucleon number = number of protons + number of neutrons

Then:

number of neutrons = nucleon number – number of protons

= A – Z

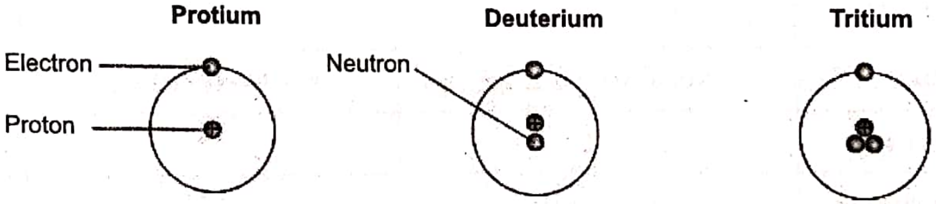


For example, an atom of aluminium has a nucleon number of 27 and a proton number of 13. So an aluminium atom has 27 – 13 = 14 neutrons.

Isotopes

Atoms of the same element which have same atomic number but different mass number are called isotopes. Isotopes differ from each other in the number of neutrons but not in the number of protons. Isotopes of a particular element have the same chemical properties because they have the same number of electrons. They have slightly different physical properties, such as small differences in density melting point, boiling point, etc.

Hydrogen has three isotopes. The atomic structure and isotopic symbols for the three isotopes of hydrogen are shown in Figure below. When writing generally about isotopes, chemists also name them by omitting the proton number and placing the nucleon number after the name. For example, the isotopes of hydrogen can be called hydrogen-1, hydrogen-2 and hydrogen-3.



	Protium	Deuterium	Tritium
Protons	1	1	1
Neutrons	0	1	2
Isotopic symbol	^1_1H	^2_1H	^3_1H

In a neutral atom the number of positively charged protons in the nucleus equals the number of negatively charged electrons outside the nucleus. When an atom gains or loses electrons, ions are formed, which are electrically charged.

For example:

Cl	+	e^-	→	Cl^-
Chlorine atom 17 protons 17 electrons		1 electron gained		chloride ion 17 protons 18 electrons

The chloride ion has a single negative charge because there are 17 protons (+) and 18 electrons (–).

Mg	→	Mg^{2+}	+	$2e^-$
Magnesium atom 12 protons 12 electrons		Magnesium ion		2 electrons removed 12 protons 10 electrons

The Magnesium ion, Mg^{2+} has a charge of 2+ because it has 12 protons (+) but only 10 electrons (–).

Arrangement of Electrons in Atoms

As the number of protons in the nucleus increases, the mass of an atom of the element increases. After hydrogen, this increase in mass is also due to the neutrons in the nucleus.

Element	Protons	Neutrons	Relative atomic mass
H	1	0	1
He	2	2	4
Li	3	4	7
Be	4	5	9
B	5	6	11
C	6	6	12

The addition of electrons to form new atoms is not quite so straightforward because they go into different orbitals (regions in space that can hold a certain number of electrons, and which have different shapes). The electrons also exist in different energy levels (sometimes called shells) depending on how close to, or far away from, the nucleus they are.

Shells, Subshells and Orbitals

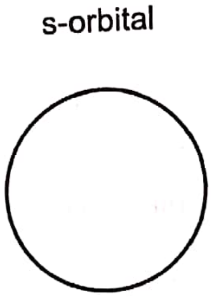
Electrons within an atom can be assessed according to the shell, subshell, and orbital to which they are assigned. These assessments are based on the **Quantum Mechanical Model.** Shells are numbered as n=1, 2, 3, 4, etc. and increase in size and energy as they get further away from the nucleus. Shells can be subdivided into subshells. The maximum number of subshells is equivalent to the shell number. For example, when n=1 (first shell), only one subshell (s) is possible and when n=2 (second shell), two subshells are possible (i.e s and p).

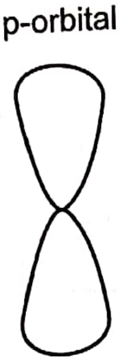
There are four different types of subshells. These various types of subshells are denoted by the letters s, p, d, and f. Each subshell has a maximum number of electrons which it can hold: **s** - 2 electrons, **p** - 6 electrons, **d** - 10 electrons, and **f** - 14 electrons. The **s** subshell is the lowest energy subshell and the **f** subshell is the highest energy subshell.

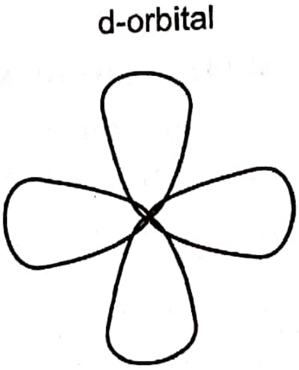
As was mentioned previously, the shell number is equal to the possible number of subshells. Thus, when n=1, the only subshell possible is the **1s** subshell. When n=2, two subshells are possible the **2s** and **2p**. When n=3, three subshells are possible the **3s**, **3p**, and **3d**. This means that in the first shell only two electrons are possible and they would be found in the 1s (2 electrons) subshell. In the second shell, 8 electrons are possible and would be found in the **2s** (2 electrons) and the **2p** (6 electrons) subshells.

Each subshell is further divided into orbitals. An orbital is defined as a region of space in which an electron can be found. Only two electrons are possible per orbital. Thus, the **s** subshell may contain only one orbital and the **p** subshell may contain three orbitals.

Each orbital has its own distinct shape. An **s** orbital found in an **s** subshell is spherical, **p** orbitals found in **p** subshells are two-lobed, and **d** orbitals found in **d** subshells are four-lobed. The shapes of the **s**, **p**, and **d** orbitals are illustrated in the figure below.



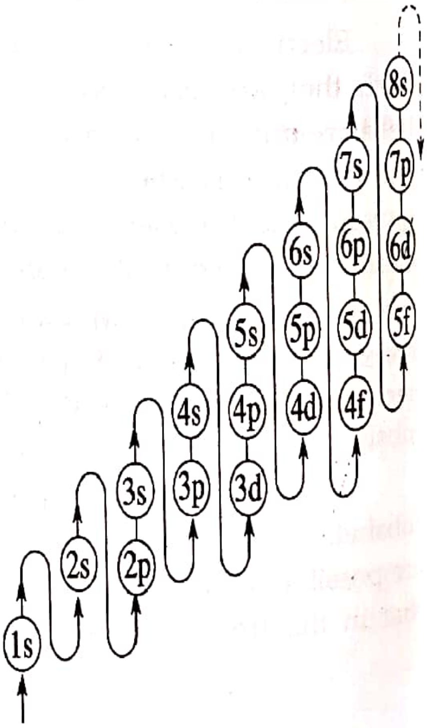




Since there are three possible orbitals per p subshell, each orbital adopts its own orientation. The p_x orbital lies along the **x** axis, the p_y orbital lies along the **y** axis, and the p_z orbital lies along the **z** axis.

Electronic configuration is the arrangement of electrons in an atom in different shells sub-shells and orbitals. After the discovery of the shells and sub-shells, various physical and chemical properties of the elements were linked to the electronic configuration. As the number of protons increases, the electron energy levels fill up in the following sequence: 1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p...

Electrons fill into shells, subshells, and orbitals according to provision for the lowest energy arrangement or ground state electron configuration of an atom. This phenomenon is referred to as the **Aufbau process.** There are three rules which will be followed in order to attain the lowest energy arrangement of electrons.

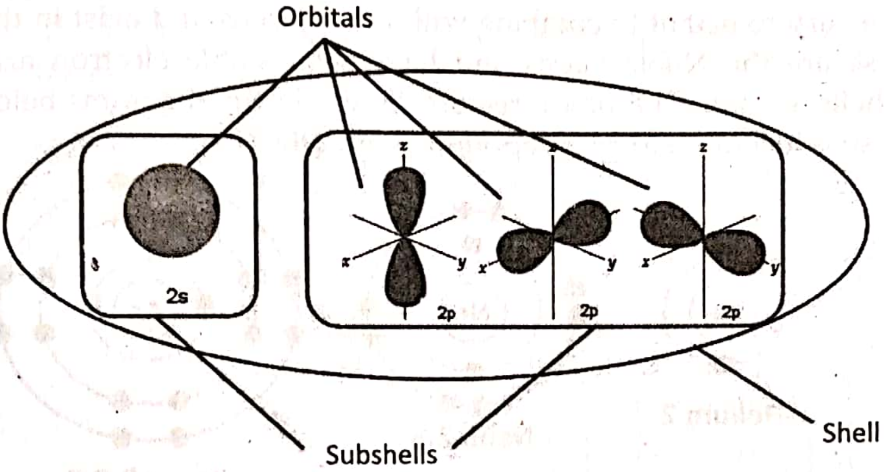


- **Rule 1** - Lowest energy orbitals fill first. Thus, the filling pattern s **1s, 2s, 2p, 3s, 3p, 4s, 3d,** etc. Since the orbitals within a subshell are degenerate (of equal energy), the entire subshell of a particular **orbital** type is filled before moving to the next subshell of higher energy.
- **Rule 2 - Pauli Exclusion Principle -** Only two electrons are permitted per orbital and they must be of opposite spin. If one electron within an orbital possesses a clockwise spin, then the second electron within that orbital will possess a counterclockwise spin. Two electrons with opposite spins found in the same orbital are referred to as being paired.
- **Rule 3-** Hund's Rule - The most stable arrangement of electrons in a subshell occurs when the maximum

number of unpaired electrons exist, all possessing the same spin direction. This occurs due to the degeneracy of the orbitals, all orbitals within a subshell are of equal energy. Electrons are repulsive to one another and only pair after all of the orbitals have been singly filled.

When writing electron configurations for atoms, the shorthand symbol for a subshell followed by a superscripted number which represents the number of electrons in that subshell is used. For example, a Carbon atom with 6 electrons would have the electron configuration: **$1s^2$ $2s^2$ $2p^2$**. A possible arrangement within the **2p** subshell would be to find one of the electrons in the $2p_x$ orbital and the second electron in the **$2p_y$** orbital.

Here's a graphic to explain the difference in Shell, sub shell and Orbitals.



- All electrons that have the same value for n (the principle quantum number) are in the same **shell**
- Within a shell (same n), all electrons that share the same l (the angular momentum quantum number, or orbital shape) are in the same **sub-shell**
- When electrons share the same n, l, and ml, we say they are in the same **orbital** (they have the same energy level, shape, and orientation)

Example 1

An atom, X, has a proton number of 16. Deduce the electron configuration of this atom.

Answer: The proton number is 16, so the atom must also contain 16 electrons. Referring back to Figure, we can count upwards until 16 electrons have been used. This means the 1s-orbital, the 2s- and 2p-orbitals and the 3s-orbital are filled, using up 12 of the 16 electrons. The remaining four electrons must go into the 3p-orbital, giving the electron configuration $1s^2$, $2s^2$, $2p^6$, $3s^2$, $3p^4$.

Example 2

X forms an ion, X^{2-}. What is the electron configuration of the ion?

Answer: The ion contains an extra two electrons compared with the atom. This means that it contains a total of (16 + 2) or 18 electrons. You can see that these extra two electrons will fit into the remainder of the 3p-orbital giving an electronic configuration of $1s^2$, $2s^2$, $2p^6$, $3s^2$, $3p^6$ for the ion X^{2-}.

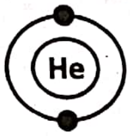
CHEMICAL BONDING

Chemical bond refers to the strong electrical force of attraction between the atoms or ions in the structure. The combining power of an atom is sometimes referred to as its valency and its value is linked to the number of outer electrons of the original uncombined atom.

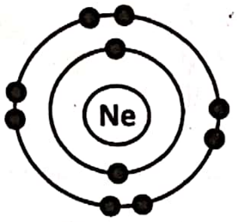
Why do atoms form bonds?

Atoms form chemical bonds in order to make their outer electron shells more stable. The type of chemical bond maximizes the stability of the atoms that form it. An ionic bond, where one atom essentially donates an electron to another, forms when one atom becomes stable by losing its outer electrons and the other atoms becomes stable (usually by filling its valence shell) by gaining the electrons. Covalent bonds form when sharing electrons results in the highest stability.

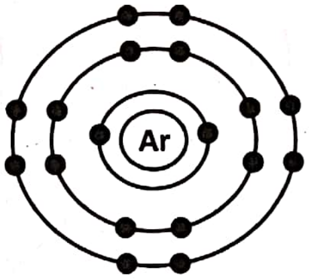
Some atoms are very reluctant to combine with other atoms and exist in the air around us as single atoms. These are the Noble Gases and have very stable electron arrangements e.g. because their outer shells are full. The first three are shown in the diagrams below and explains why Noble Gases are so reluctant to form compounds with other elements.



Helium 2



Neon 2,8



Argon 2,8,8

All other atoms therefore, bond together to become electronically more stable, that is to become like Noble Gases in electron arrangement. The **octet rule** states that elements gain or lose electrons to attain an electron configuration of the nearest noble gas.

Bonds and Valence Electrons

The very first electron shell only holds two electrons, a hydrogen atom (atomic number 1) has one proton and a lone electron, so it can readily share its electron with the outer shell of another atom. A helium atom (atomic number 2), has two protons and two electrons. The two electrons complete its outer electron shell (the only electron shell it has), plus the atom is electrically neutral this way. This make helium stable and unlikely to form a chemical bond.

Past Hydrogen and Helium, it's easiest to apply the octet rule to predict whether two atoms will form bonds and how many bonds they will form. Most atoms need 8 electrons to complete their outer shell. So, an atom that has 2 outer electrons will often form a chemical bond with an atom that lacks two electrons to be "complete".

Types of Chemical Bond

The different forms of bonding considered here are:

1. Ionic bond
2. Covalent bond
3. Coordinate covalent bond
4. Metallic bond

IONIC BONDS

In chemical bonds, atoms transfer electrons. One or more atoms lose electrons and other atoms gain them in order to produce a noble gas electron configuration, the bond is called an ionic bond. The electrostatic force of attraction between oppositely charged ions results in the formation of ionic bond or electrovalent bond. Compounds involve in ionic bond are known as ionic compound or electrovalent compound. In figure below we can see that:

- the sodium ion has the electronic structure $[2, 8]^+$, the same as that of neon
- the chloride ion has the electronic structure $[2, 8, 8]^-$, the same as that of argon.

The strong force of attraction between the positive and negative ions in the ionic crystal lattice results in an ionic bond. An ionic bond is sometimes called an electrovalent bond. In an ionic structure, the ions are arranged in a regular repeating pattern. As a result of this, the force between one ion and the ions of opposite charge that surround it is very great. In other words, ionic bonding is very strong.

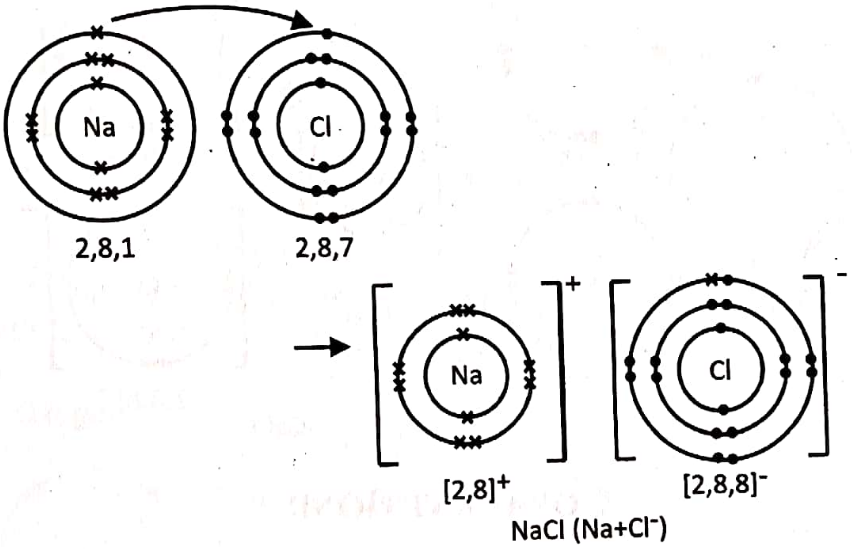
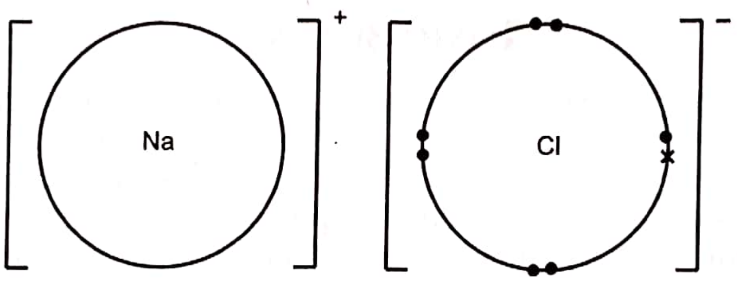


Fig: Formation of Sodium and Chlorine ion

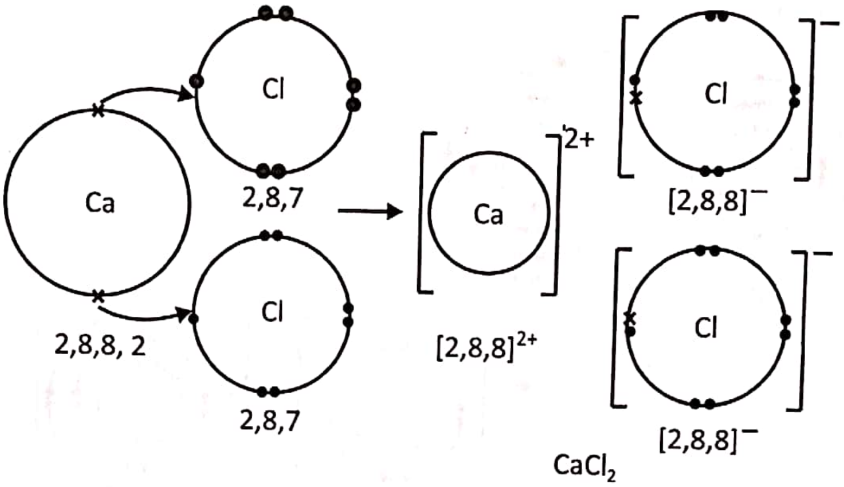
Dot-and-cross Diagrams

You will notice that in figure above we used dots and crosses to show the electronic configuration of the chloride and sodium ions. This helps us keep track of where the electrons have come from. It does not mean that the electron transferred is any different from the others. Diagrams like this are called dot-and-cross diagrams. When drawing a dot-and-cross diagram for an ionic compound it is usually acceptable to draw the outer electron shell of the metal ion without any electrons. This is because it has transferred these electrons to the negative ion. Figure below shows the outer shell dot-and-cross diagram for sodium chloride. A dot-and-cross diagram shows:

- the outer electron shells only
- that the charge of the ion is spread evenly, by using square brackets
- the charge on each ion, written at the top right-hand corner of the square brackets.



Each calcium atom has two electrons in its outer shell, and these can be transferred to two chlorine atoms. By losing two electrons, calcium atom achieves the electronic configuration [2,8,8] (Figure below). The two chlorine atoms each gain one electron to achieve the electronic configuration [2,8,8]. [2,8,8] is the electronic configuration of argon; it is a 'noble-gas configuration'. In this way calcium and chloride ions are formed which combine to form calcium chloride.



COVALENT BOND

When two non-metal atoms combine, they share one, or more, pairs of electrons. A shared pair of electrons is called a single covalent bond, or a bond pair. A single covalent bond is represented by a single line between the atoms: for example, H-H. Hydrogen gas forms the simplest covalent bond in the diatomic hydrogen molecule. For example, for attaining the nearest noble gas configuration, each hydrogen atom share its valence electron with other hydrogen atom and form a covalent bond in hydrogen molecule.

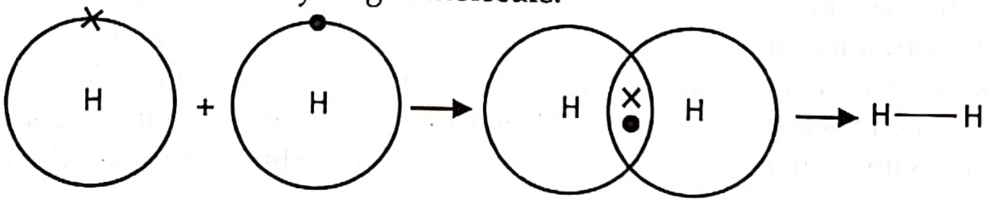
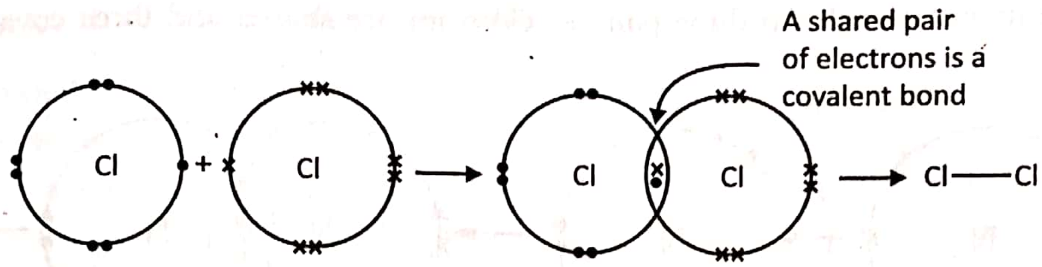


Fig: Hydrogen atoms sharing a pair of electron

The halogens such as chlorine also exist as diatomic gases by forming covalent bonds. You can see in the diagram below that when chlorine atoms combine not all the electrons are used in bonding. The pairs of outer-shell electrons not used in bonding are called **lone pairs**. Each atom in a chlorine molecule has three lone pairs of electrons and shares one bonding pair of electrons



A shared pair of electrons is a covalent bond

Chlorine atoms (2,8,7)

Chlorine molecule: each chlorine is now 2,8,8

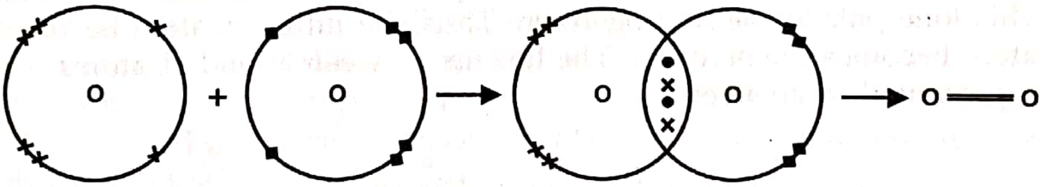
The nitrogen and oxygen which makes up the bulk of the atmosphere also exhibits covalent bonding in forming diatomic molecules.

Multiple Covalent Bonds

Some atoms can bond together by sharing two pairs of electrons. We call this a double covalent bond. A double covalent bond is represented by a double line between the atoms: for example, O=O. The dot-and-cross diagrams for oxygen and carbon dioxide all of which have double covalent bonds, are shown in Figure below.

- In order to form an oxygen molecule, each oxygen atom needs to gain two electrons to complete its outer shell. So two pairs of electrons are shared and two covalent bonds are formed.
- For carbon dioxide, each oxygen atom needs to gain two electrons as before. But the carbon atom needs to gain four electrons to complete its outer shell. So two oxygen atoms each form two bonds with carbon, so that the carbon atom has eight electrons around it.

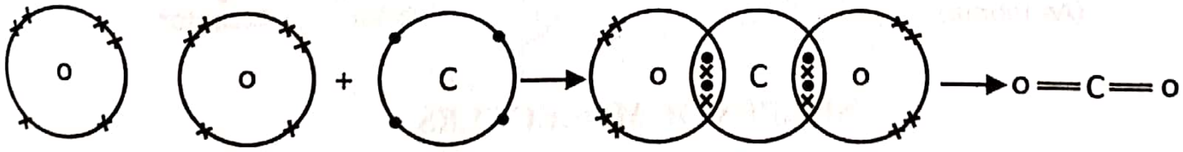
Oxygen



Two oxygen atoms (2,6)

Oxygen molecule

Carbon dioxide

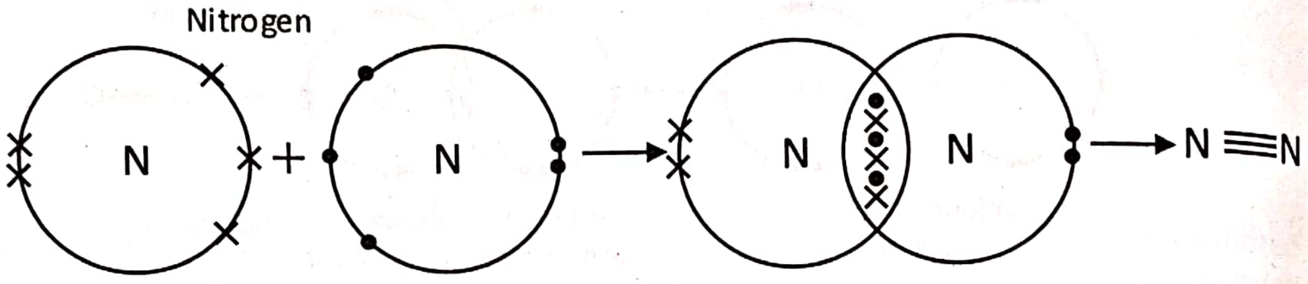


Two oxygen atoms (2,6)

Carbon atom (2,4)

Carbon dioxide molecule

Atoms can also bond together by sharing three pairs of electrons. We call this a triple covalent bond. Diagram below shows a dot-and-cross diagram for the triple-bonded nitrogen molecule. In order to form a nitrogen molecule, each nitrogen atom needs to gain three electrons to complete its outer shell. So three pairs of electrons are shared and three covalent bonds are formed.



Two Nitrogen atoms (2,5)

Nitrogen Molecule

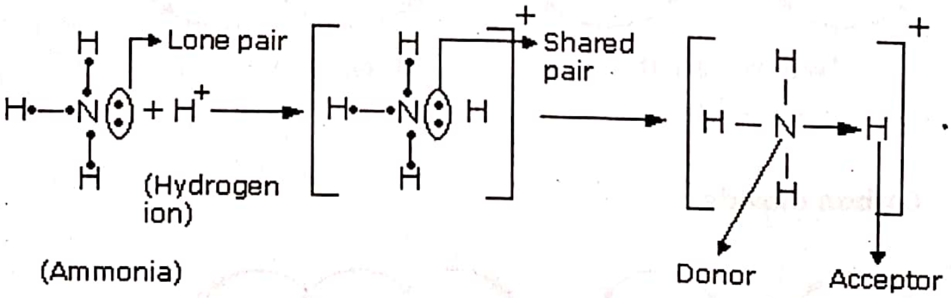
COORDINATE COVALENT BOND

When shared pair of the electron comes from only one atom and not one each from the two atoms involved in the bonding then it is called as coordinate or dative bonding. The atoms which donates the electron to form co-ordinate covalent bonding or dative bonding is called as the donor atom, while the atom which accepts the pair of electron for bonding is called as the acceptor atoms. For dative covalent bonding we need:

- one atom having a lone pair of electrons
- a second atom having an unfilled orbital to accept the lone pair; in other words, an electron-deficient compound.

Thus coordinate bond can also be explained as the bond formed between the donor and acceptor atoms. A coordinate bond is represented by an arrow (→) starting from the donor atom and ending in the acceptor atom.

In ammonia, the nitrogen atom has a lone pair of electrons after completing its outer shell. It donates this lone pair to the hydrogen ion. Thus, the nitrogen atom becomes the donor. The hydrogen atom becomes the acceptor. The linkage between N and H atoms is called coordinate bond. It is represented by an arrow →.



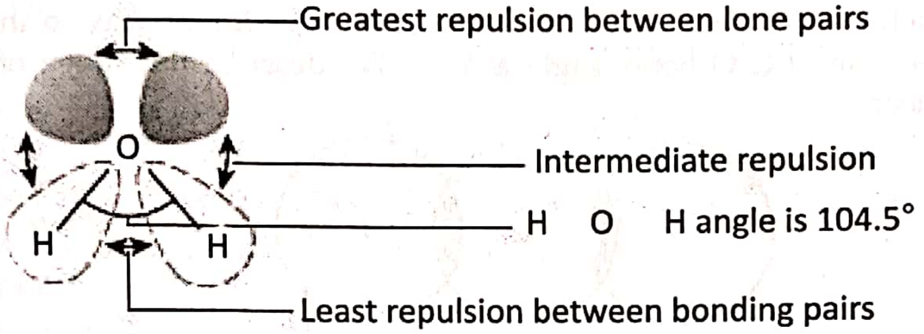
SHAPES OF MOLECULES

Electron-pair repulsion theory

Because all electrons have the same (negative) charge, they repel each other when they are close together. So, a pair of electrons in the bonds surrounding the central atom in a molecule will repel other electron pairs. This repulsion forces the pairs of electrons apart until the repulsive forces are minimised. The shape and bond angles of a covalently bonded molecule depend on:

- the number of pairs of electrons around each atom
- whether these pairs are lone pairs or bonding pairs.

Lone pairs of electrons have a more concentrated electron charge cloud than bonding pairs of electrons. Their cloud charges are wider and slightly closer to the nucleus of the central atom. This results in a different amount of repulsion between different types of electron pairs. The order of repulsion is lone pair–lone pair (most repulsion) > lone pair–bond pair > bond pair–bond pair (least repulsion). Diagram below shows the repulsions between lone pairs and bonding pairs in a water molecule.

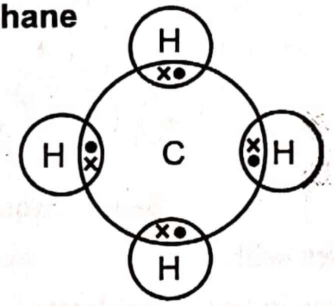

Greatest repulsion between lone pairs
O
Intermediate repulsion
H
H
H O H angle is 104.5°
Least repulsion between bonding pairs

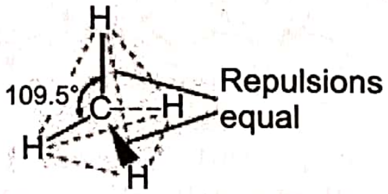
Water has two bonding pairs of electrons and two lone pairs of electrons. The greatest electron pair repulsion is between the two lone pairs. This results in the bonds being pushed even closer together. The shape of the water molecule is a nonlinear V shape. The H-O-H bond angle is 104.5°.

Working out the shapes of molecules

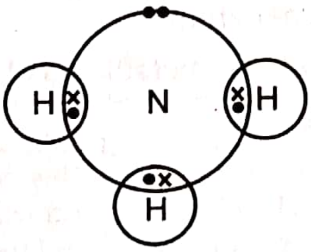
The differences in electron-pair repulsion determine the shape and bond angles in a molecule. Diagram below compares the shapes and bond angles of methane and ammonia and water. Each of these molecules has four pairs of electrons surrounding the central atom. Note that in drawing three-dimensional diagrams, the triangular 'wedge'. is the bond coming towards you and the dashed black line is the bond going away from you.

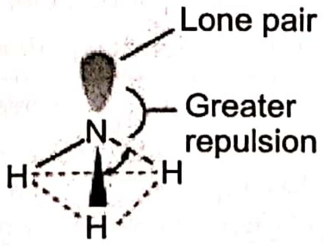
Methane





Ammonia

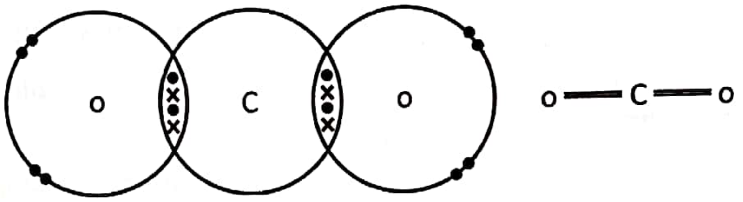




Methane has four bonding pairs of electrons surrounding the central carbon atom. The equal repulsive forces of each bonding pair of electrons results in a tetrahedral structure with all H C H bond angles being 109.5°.

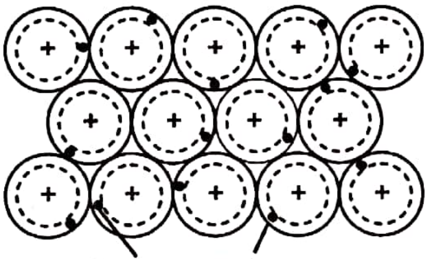
In ammonia, the tetrahedral arrangement of the electron pairs around the central atom becomes distorted. Ammonia has three bonding pairs of electrons and one lone pair. As lone pair–bond pair repulsion is greater than bond pair–bond pair repulsion, the bonding pairs of electrons are pushed closer together. This gives the ammonia molecule a triangular pyramidal shape. The H-N-H bond angle is about 107°.

Carbon dioxide has two carbon–oxygen double bonds and no lone pairs. The four electrons in each double bond repel other electrons in a similar way to the two electrons in a single bond. So, the O C O bond angle is 180°. We describe the shape of the carbon dioxide molecule as linear.

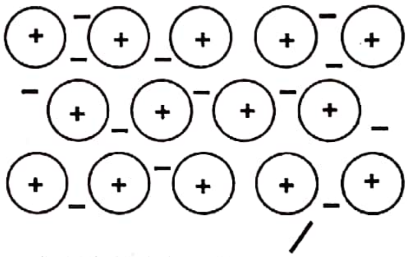


METALLIC BONDING

In a metal, the atoms are packed closely together in a regular arrangement called a lattice. Metal atoms in a lattice tend to lose their outer shell electrons and become positive ions. The outer shell electrons occupy new energy levels and are free to move throughout the metal lattice. We call these electrons, delocalised electrons (mobile electrons). Delocalised electrons are electrons that are not associated with any one particular atom or bond. Metallic bonding is strong. This is because the ions are held together by the strong electrostatic attraction between their positive charges and the negative charges of the delocalised electrons. This electrostatic attraction acts in all directions.



Outer-shell electrons



'Sea' of delocalised electrons

The strength of metallic bonding increases with:

- increasing positive charge on the ions in the metal lattice
- decreasing size of metal ions in the lattice
- increasing number of mobile electrons per atom.

The comparison of ionic bond, covalent bond and metallic bond

Ionic Bond	Covalent Bond	Metallic Bond
The transfer of electrons between two atoms having different electro negativities	This bond is formed by the mutual sharing of electrons between same or different	This bond is formed due to the attraction between positive ions and the mobile electrons in a metal

forms this bond.	elements.	lattice.
This is a strong bond due to electrostatic force of attraction.	This is also a fairly strong bond because the electron pair is strongly attracted by two nuclei.	This is a weak bond due to the simultaneous attraction of the electrons by a large number of positive ions.
It is farmed between metal + non metal.	It is farmed between non-metal atoms	It is farmed in pure metals
This bond makes substances hard and brittle.	This bond makes substances hard and incompressible.	This bond makes substances malleable and ductile.

INTERMOLECULAR FORCES

The forces within molecules are strong (covalent bonding, Ionic bonding, etc) and are called intramolecular forces. However, the forces between molecules are much weaker. We call these forces intermolecular forces. These are:

- van der Waals' forces (which are also called dispersion forces and temporary dipole–induced dipole forces)
- hydrogen bonding.

In order to understand how intermolecular forces work, we first have to know about electronegativity and bond polarity.

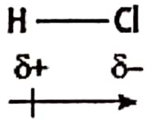
Electronegativity

Electronegativity is the ability of a particular atom, which is covalently bonded to another atom, to attract the bond pair of electrons towards itself. The greater the value of the electronegativity, the greater the power of an atom to attract the electrons in a covalent bond towards itself.

Polarity in molecules

When the electronegativity values of the two atoms forming a covalent bond are the same, the pair of electrons is equally shared. We say that the covalent bond is **non-polar.** For example, hydrogen (H_2), chlorine (Cl_2) and bromine (Br_2) are non-polar molecules. When a covalent bond is formed between two atoms having different electronegativity values, the more electronegative atom attracts the pair of electrons in the bond towards it.

We denote the less electronegative atom with the partial positive charge δ+ ('delta positive'); the more electronegative atom with the partial negative charge δ– ('delta negative') and we say that the bond is polar (or that it has a dipole). Diagram below shows the polar bond in a hydrochloric acid molecule.


$$\overset{\delta+}{H}-\overset{\delta-}{Cl}$$

Van der Waals' forces

Noble gases such as Neon and Argon exist as isolated atoms. Noble gases can be liquefied, but at very low temperatures, so there must be very weak forces of attraction between their atoms. These weak forces keep the atoms together in the liquid state. Bromine is a non-polar molecule that is liquid at room temperature. The weak forces of attraction are keeping the bromine molecules together at room temperature. These very weak forces of attraction are called van der Waals' forces. Van der Waals' forces exist between all atoms or molecules. So, how do van der Waals' forces arise?

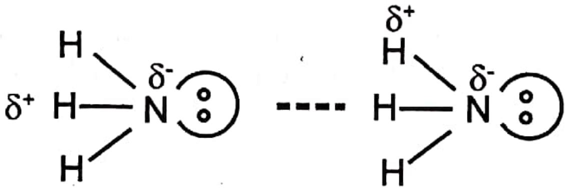
The electron charge clouds in a non-polar molecule (or atom) are constantly moving. It often happens that more of the charge cloud is on one side of the molecule than the other. This means that one end of the molecule has, for a short moment, more negative charge than the other. A temporary dipole is set up. This dipole can set up (induce) a dipole on neighbouring molecules. As a result of this, there are forces of attraction between the δ+ end of the dipole in one molecule and the δ– end of the dipole in a neighbouring molecule. These dipoles are always temporary because the electrons clouds are always moving. van der Waals' forces are sometimes called temporary dipole–induced dipole forces.

Hydrogen bonding

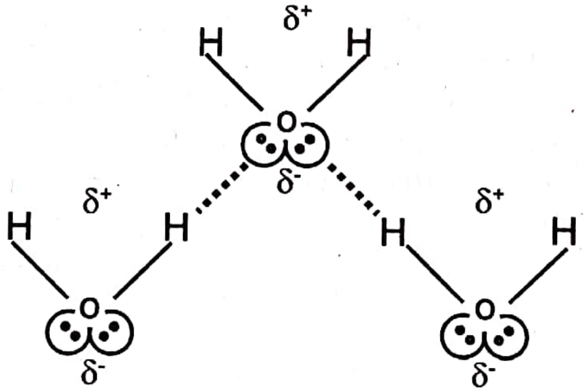
Hydrogen bonding is the strongest type of intermolecular force. For hydrogen bonding to occur between two molecules we need:

- one molecule having a hydrogen atom covalently bonded to F, O or N (the three most electronegative atoms)
- a second molecule having a F, O or N atom with an available lone pair of electrons.

When a hydrogen atom is covalently bonded to a highly electronegative atom, the bond is highly polarised. The δ+ charge on the hydrogen atom is high enough for a bond to be formed with a lone pair of electrons on the F, O or N atom of a neighbouring molecule (Figure below). The force of attraction is about one-tenth of the strength of a normal covalent bond.



Water has two hydrogen atoms and two lone pairs per molecule (Figure below). So water is extensively hydrogen bonded with other water molecules. It has an average of two hydrogen bonds per molecule.



Ammonia is less extensively hydrogen bonded than water. It can form, on average, only one hydrogen bond per molecule. Although each ammonia molecule has three hydrogen atoms attached to the nitrogen atom, it has only one lone pair of electrons that can be involved in hydrogen bond formation.

CHEMISTRY (MCQS)

Note: **Answers are Bold and Underlined:**

1. **The nucleus of an atom consists of:**
   (a) Protons + electrons (b) Only protons
   (c) Protons + neutrons + electrons (d) **Protons and neutrons**
2. **Which of the following pairs is incorrect?**
   (a) Atom: Smallest indivisible part of element. (b) Molecule: Unit of a compound.
   (c) **Heterogeneous mixture of two or more things.**
   (d) Alloy: Mixture of two or more metals.
3. **Atomic weight of uranium $_{92}U^{238}$ is:**
   (a) 337 (b) **238** (c) 226 (d) 92
4. **Which of the following is a chemical change?**
   (a) Evaporation of water. (b) **Burning of candle.**
   (c) Formation of Ice (d) Liquefaction of air.
5. **Which of the following does not belong to the halogen family?**
   (a) Chlorine (b) Fluorine (c) Bromine (d) **Morphine**
6. **Which among the following is not a noble gas?**
   (a) Argon (b) Radon (c) Neon (d) **Rayon**
7. **Which of the following is the hardest substance?**
   (a) Copper (b) **Diamond**
   (c) Iron (d) Silicon
8. **The chemical name of laughing gas is:**
   (a) **Nitrous oxide** (b) Nitric oxide
   (c) Nitrogen dioxide (d) Nitrogen peroxide
9. **The nucleus of a hydrogen atom consists of:**
   (a) One proton + one neutron (b) One proton + two neutrons
   (c) One proton only (d) **All of these**
10. **The bond formed by transfer of electrons from one atom to another is:**
    (a) **Ionic** (b) Covalent
    (c) Metallic (d) Either (a) or (b)
11. **Mass of an electron is:**
    (a) 9.11×10^{-19} kg (b) 1.6×10^{-19} kg
    (c) **9.11×10^{-31} kg** (d) 1.6×10^{31} kg
12. **The nuclei of most of the atoms contain nearly ______% of the mass of the atoms.**
    (a) 50 (b) 80 (c) 90 (d) **99.9**

13. **The atomic number of an atom is determined by number of:**
(a) **Proton** (b) Neutron (c) Electron (d) None of these

14. **The electron was discovered by:**
(a) Chadwick (b) Neil's Bohr (c) Millikan (d) **J. J. Thomson**

15. **Isotopes of an element have the same number of:**
(a) Neutrons (b) **Protons**
(c) Protons plus neutrons (d) Electrons

16. **The term nucleon is used to refer to:**
(a) An electron (b) A photon
(c) A positron (d) **Either a neutron or a proton**

17. **Atoms are composed of:**
(a) Electrons only (b) Protons only
(c) Electrons and Protons (d) **Electrons and Nuclei**

18. **Who suggested that the most of the mass of atom is located in nucleus?**
(a) Bohr (b) Thomson (c) **Rutherford** (d) Avogadro

19. **An atom of an element with mass number 23 and atomic number 11 will have:**
(a) 11 neutrons, 12 protons and 11 electrons
(b) 11 protons, 12 neutrons and 11 electrons
(c) 11 protons, 12 electrons and 11 neutrons
(d) 23 protons and 11 electrons

20. **Dalton's atomic theory states that the smallest particle which can exist independently is:**
(a) **An atom** (b) A molecule (c) A cation (d) An anion

21. **The neutral atom's two isotopes differ in the number of:**
(a) Electron shells (b) Protons (c) Valence electrons (d) **Neutrons**

22. **Chadwick got the Nobel Prize for the discovery of:**
(a) Protons (b) **Neutrons** (c) Electrons (d) Mesons

23. **Mass number is equal to the:**
(a) Number of protons + number of electrons
(b) **Number of protons + number of neutrons**
(c) Number of neutrons + number of electrons (d) Number of electrons

24. **The other name of $^{1}_{1}H$ is:**
(a) **Protium** (b) Tritium (c) Deuterium (d) Proton

25. **The fixed circular paths around the nucleus are called:**
(a) **Orbits** (b) Orbitals (c) Nucleons (d) Mesons

26. **Protons are:**
(a) Positively-charged particles with negligible mass.
(b) **Positively-charged particles with significant mass.**

(c) Negatively-charged particles with negligible significant mass.

(d) Neutral particles with significant mass.

27. If Z represents the atomic number and A represents mass number, then the number of neutrons in an atom can be computed as:

(a) A + Z
(b) A – Z
(c) Z – A
(d) Z

28. If Z represents the atomic number and A represents mass number, then the number of electrons in an atom can be computed as

(a) A + Z
(b) A/Z
(c) Z – A
(d) Z

29. Proton was discovered by:

(a) Rutherford
(b) Goldstein
(c) Chadwick
(d) J. J. Thomson

30. The number of electrons in the outermost shell in the atom of an inert element is:

(a) 0
(b) 1
(c) 2
(d) 8

31. Inert gases do not react with any other element because:

(a) Their nucleus is very small.

(b) The temperature is not high enough.

(c) The pressure is not high enough.

(d) Their outermost electron level is filled with 8 electrons.

32. Two or more atoms combine to form:

(a) A cation
(b) An anion
(c) A molecule
(d) An ion

33. How many electrons are required in the outermost shell of an element for it to be stable?

(a) 4
(b) 6
(c) 8
(d) 2

34. The tendency of atoms to attain maximum of eight electrons in the valance shell is known as:

(a) Octet rule
(b) Tirad rule
(c) Tetrad rule
(d) Duplet rule

35. The driving force for making a bond is to:

(a) Make solid compounds

(b) Make gaseous substances

(c) Attain electronic configuration of noble gases

(d) Make different compounds

CHAPTER 8

FOOD SCIENCE

We require food to grow, reproduce and maintain good health. Without food, our bodies could not stay warm, build or repair tissues or maintain a heartbeat. Eating the right foods can help us avoid certain diseases or recover faster when illness occurs. These and other important functions are fuelled by chemical substances in our food called *nutrients*.

BALANCED DIET

> ***"Let thy food be thy medicine": Hippocrates***

A balanced diet should not only take care of the different types of nutrients but also consider the energy requirements of the individual. This is because different people have different lifestyles and varied nature of work. A man with sedentary habits does not require as much energy as the man who is on his feet for most of the day. The energy requirement is measured in terms of calories. The calorie requirement depends on the age, gender, height, weight, occupation and state of health.

"A balanced diet is a diet which includes right amount of all the nutrients such as proteins, vitamins, minerals, fats, carbohydrates, etc. for proper growth, development and normal functioning of the body."

A balanced diet is required for the growth and development of a person especially the children. A balanced diet has direct relation with the health of a person. A young boy of 15 requires more calories or energy than an adult man who does not do heavy work. Similarly, lactating mothers require high energy and high protein diet for good lactation.

Amount of Energy Required by People of Different Age Groups

Person	Required kilo calories (approximate)
Children age in years 1-3	1200
Children age in years 4-6	1600
Children age in years 7-9	2000
Children age in years 10-12	2500
Women who do not work	2090
Women doing hard work	3000
Men who do not work	3400
Men doing hard work	4500

Components of Balanced Diet

1. **Carbohydrates** - our main source of energy.
2. **Proteins** - essential to growth and repair of muscles and other body tissues.
3. **Fats** - one source of energy and important in relation to fat soluble vitamins.
4. **Vitamins** - water and fat soluble vitamins play important roles in many chemical processes in the body.
5. **Minerals** - inorganic elements occurring in the body. These are critical to body's normal functioning.
6. **Water** - essential to normal body functioning - as a vehicle for carrying other nutrients and because 65-75% of the human body is water.
7. **Dietary Fibre** - the fibrous indigestible portion of our diet essential to health of the digestive system.

Calorie

A calorie (cal) is the amount of heat energy required to raise the temperature of 1g of water 1°C from 14° to 15°C. A kilocalorie (kcal) is the amount of heat required to raise the temperature of 1kg of water 1°C.

BIOMOLECULES

Biomolecules are molecules that occur naturally in living organisms. Biomolecules include macromolecules like proteins, carbohydrates, lipids and nucleic acids. It also includes small molecules like primary and secondary metabolites and natural products. Biomolecules consists mainly of carbon and hydrogen with nitrogen, oxygen, sulphur, and phosphorus.

Classes of Biomolecules

There are four major classes of biomolecules:

- Carbohydrates
- Proteins
- Lipids
- Nucleic acids

Note: We will discuss carbohydrates, proteins and lipids in this chapter while nucleic cids will be discussed in chapter cell biology.

CARBOHYDRATES

Carbohydrates are the human body's key source of energy, providing 3.9 calories of nergy per gram. When carbohydrates are broken down by the body, glucose is produced. arbohydrates are organic compounds, these comprise of only carbon, hydrogen and oxygen. he hydrogen: oxygen ratio is usually is 2:1. The empirical formula of carbohydrates is $m(H_2O)n$ (where m can be different from n). Carbohydrates are also known as saccharides, the ord saccharide comes from Greek word *sakkron* which means sugar.

arbohydrates Classification

Carbohydrates are classified into simple carbohydrates (monosaccharide, oligosaccharides) nd complex carbohydrates (polysaccharides).

Monosaccharides

From Greek, mono = one and sakkron = sugar. Monosaccharides are often called simple sugars. They are the simplest sugars and cannot be hydrolyzed. The general formula is $C_n(H_2O)_n$. The monosaccharides are subdivided into trioses, tetrose, pentoses, hexoses, heptoses etc., Examples of monosaccharides are glucose, fructose, erythrulose, ribulose, etc.

- **Glucose:** The immediate source of energy for cellulat respiration and "blood sugar".
- **Galactose:** A sugar in milk and yogurt.
- **Fructose:** A sugar found in honey.

However, glucose is considered as the fundamental unit of carbohydrates.

Oligosaccharides or Oligosaccharoses

In Greek, Oligo means few. Oligosaccharides are compound sugars that yield 2 to 10 molecules of the same or different monosaccharides on hydrolysis. Oligosaccharide yielding 2 molecules of monosaccharides on hydrolysis is known as a disaccharide, and the ones yielding 3 or 4 monosaccharides are known as trisaccharides and tetrasaccharides, respectively and so on. The general formula of disaccharides is $C_n (H_2O)_{n-1}$ and that of trisaccharides is $C_n(H_2O)_{n-2}$ and so on. Two monosaccharide can be linked together to form a "double" sugar or disaccharide. Three common disaccharides are:

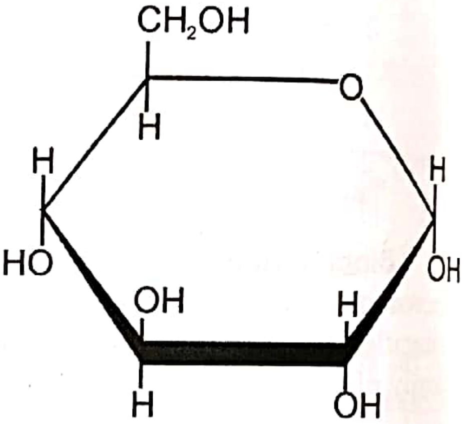


Fig: Structure of Glucose

- **Sucrose** — common table sugar = glucose + fructose
- **Lactose** — major sugar in milk = glucose + galactose
- **Maltose** — product of starch digestion = glucose + glucose

Polysaccharides

In Greek, poly means many. *Polysaccharides* are compound sugars and yield more than 10 molecules of monosaccharides on hydrolysis. They are further classified depending on the type of molecules produced as a result of hydrolysis. They may be homo polysaccharides, i.e. monosaccharides of the same type or hetero polysaccharides, i.e. monosaccharides of different types. The general formula is $(C_6H_{10}O_5)_n$. Example of homo polysaccharides are starch, glycogen, cellulose, pectin. Hetero polysaccharides are Hyaluronic acid, and Chondroitin.

Functions of Carbohydrates

- Carbohydrates are chief energy source, in many animals; they are instant source of energy. Glucose is broken down by glycolysis/ kreb's cycle to yield ATP.
- Glucose is stored as glycogen in animals and starch in plants.
- Stored carbohydrates acts as energy source instead of proteins.
- Carbohydrates aid in regulation of nerve tissue and is the energy source for brain.
- Carbohydrates gets associated with lipids and proteins to form surface antigens, receptor molecules, vitamins and antibiotics.

- They form structural and protective components, like in cell wall of plants and micro-organisms.
- In animals they are important constituent of connective tissues.
- They participate in biological transport, cell-cell communication and activation of growth factors.
- Carbohydrates are rich in fibre content help to prevent constipation.

Sources

Carbohydrates are available in wide variety of foods, for example cereals, fruits (especially dates), honey, milk, sugar beet, potato, pasta and sugarcane.

PROTEINS

Proteins are the chief-builders of the body. They are complex molecules made up of carbon, hydrogen, oxygen and nitrogen (sometimes sulphur and phosphorus). Proteins are used to synthesize enzymes (e.g. pepsin, trypsin), hormones (e.g. insulin, adrenaline), carrier proteins (e.g. haemoglobin) and contractile proteins (e.g. myosin, actin). Normal protein requirement of an adult is 1g/kg of the body weight. However, growing children, pregnant and nursing mothers need more protein. It provides 4.1 calories of energy per gram.

Composition of Proteins

The proteins are polymers made of monomers called the amino acids. Amino acids are relatively small nitrogen-containing molecules that serve as building blocks for proteins and other organic compounds. Of the 22 amino acids in nature, 20 are present in our cells. Thousands of structural proteins, enzymes, hormones, transport molecules, neurotransmitters and immune molecules are built from these same 20 amino acids, combined together in slightly different fashions. Our body is capable of manufacturing some amino acids; others must be obtained from our food.

Mnemonic Device for Essential Amino Acids

"Help In Learning These Little Molecules Proves Truly Valuable."
Histidine, Isoleucine, Leucine, Threonine, Lysine, Methionine, Phenylalanine, Tryptophan, Valine

Non-essential Amino Acids: Non-essential amino acids can be manufactured from other amino acids or from simpler compounds already present in our body. The non-essential amino acids are alanine, asparagine, aspartic acid, cysteine, glutamic acid, glutamine, glycine, proline, serine and tyrosine. Adults can also synthesize an 11th amino acid, arginine, but infants and young children cannot produce enough to meet their metabolic needs. Therefore arginine is also called conditionally essential amino acid.

Essential Amino Acids: Nine of the 20 amino acids needed by adults cannot be synthesized in the body; they must be obtained from dietary sources. One cannot remain healthy if deprived of them for very long. The essential amino acids are histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine. Infants and children also require dietary arginine, as they cannot synthesize it efficiently.

Classification of Proteins

Classification of Proteins based on Structure of Proteins

There are four structural levels of organization to describe the complex macromolecule, protein based on the degree of complexity of the molecule. They are Primary structure, Secondary structure, Tertiary structure and Quaternary structure.

- **Primary structure of Protein** - Here protein exist as long chain of amino acids arranged in a particular sequence. They are non-functional proteins.
- **Secondary structure of protein** - If the polypeptide chain is coiled into a spiral or helix to have a three-dimensional structure, where the amino acids interact by the formation of hydrogen bonds e.g. keratin, silk fibres, etc.
- **Tertiary structure of protein** - Long polypeptide chains become more stabilizes by folding and coiling, by the formation of ionic or hydrophobic bonds or disulphide bridges, this results in the tertiary structure of protein, e.g. globulins of blood.
- **Quaternary structure of protein** - When a protein is an assembly of more than one polypeptide or subunits of its own, this is said to be the quaternary structure of protein. Examples, hemoglobin and insulin.

Classification of Proteins on the basis of Biological Function

Proteins can be grouped based on their metabolic function they perform.

- **Enzymatic Proteins:** They are the most varied and highly specialized proteins with catalytic activity. Enzymes catalyze a variety of reactions. Example: urease, catalase, cytochrome C, etc.
- **Structural Proteins:** These proteins aid in strengthening or protecting biological structures. Example: collagen, elastin, keratin, etc.
- **Transport or Carrier Proteins:** These proteins help in transport of ions or molecules in the body. Example: myoglobin, haemoglobin, etc.
- **Nutrient and Storage Proteins:** These proteins provide nutrition to growing embryos and store ions.

Functions of proteins

- Proteins build new tissues of the body and maintain and replace damaged tissues.
- Proteins carry out regulating activities as enzymes and hormones.
- Proteins are protective as antibodies.
- Proteins are responsible for movement as contractile proteins actin and myosin form basic structure of muscles.
- Keratin protein forms hair, nails, feathers, horns and beaks.
- Carrier proteins move molecules from one place to another around the body, e.g. haemoglobin.

Sources of Protein

Sources of protein are of both animal and plant origin. Some of the common sources are groundnuts, beans and pulses among plants and fish, egg, meat, milk and cheese among animal products.

LIPIDS (FATS AND OILS)

Lipids are naturally occurring organic compounds, commonly known as oils and fats. Lipids occur throughout the living world in microorganisms, higher plants and animals and also in all cell types. Lipids contribute to cell structure, provide stored fuel and also take part in many biological processes. Lipids provide 9.1 calories energy per gram.

The basic unit of lipids is a triglyceride, synthesised from glycerol (propane-1, 2, 3-triol) and fatty acids. **Triglycerides** are the chemical form in which most fat exists in food as well as in the body. The second most common class of lipids are phospholipids. They are found in membranes of animal and plants. Phospholipids contains glycerol and fatty acids, they also contain phosphoric acids and a low-molecular weight alcohol. Common phospholipids are lecithins and cephalins.

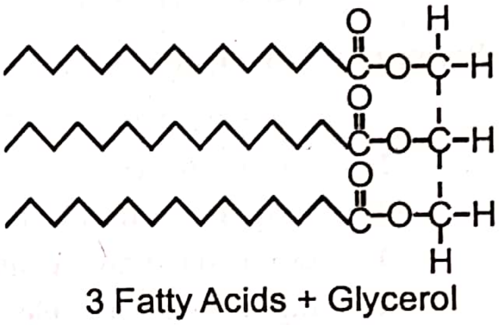


Fig: Triglyceride Molecule

Types of Lipids

Fats can be classified into saturated, trans fats and unsaturated. Most foods have both types that is saturated and unsaturated fats. But usually there is more of one kind of fat than the other.

Saturated fat

Saturated fat is solid at room temperature, which is why it is also known as "solid fat." It is mostly in animal foods, such as milk, cheese, and meat. Poultry and fish have less saturated fat than red meat. Saturated fat is also in tropical oils, such as coconut oil, palm oil, and cocoa butter. You'll find tropical oils in many snacks and in non-dairy foods, such as coffee creamers and whipped toppings. Foods made with butter, margarine, or shortening (cakes, cookies, and other desserts) have a lot of saturated fat. Saturated fat can raise your cholesterol. A healthy diet has less than 10% of daily calories from saturated fat.

Trans fat

This is a fat that has been changed by a process called hydrogenation. This process increases the shelf life of fat and makes the fat harder at room temperature. Harder fat makes crispier crackers and flakier pie crusts. Trans fat can raise your cholesterol, so eat as little trans fat as possible. You'll find it in:

- Processed foods.
- Snack foods, such as chips and crackers.
- Cookies.
- Some margarine and salad dressings.
- Foods made with shortening and partially hydrogenated oils.

Unsaturated fat

Unsaturated fat is liquid at room temperature. It is mostly in oils from plants. If you eat unsaturated fat instead of saturated fat, it may help improve your cholesterol levels. Try to eat mostly unsaturated fats. Monounsaturated fat and polyunsaturated fat are types of unsaturated fat.

- **Monounsaturated fat:** This fat is in avocado, nuts, and vegetable oils, such as canola, olive, and peanut oils. Eating foods that are high in monounsaturated fats may help lower your "bad" LDL cholesterol. Monounsaturated fats may also keep "good" HDL cholesterol levels high. But eating more unsaturated fat without cutting back on saturated fat may not lower your cholesterol.
- **Polyunsaturated fat:** This type of fat is mainly in vegetable oils such as safflower, sunflower, sesame, soybean, and corn oils. Polyunsaturated fat is also the main fat found in seafood. Eating polyunsaturated fat in place of saturated fat may lower LDL cholesterol. The two types of polyunsaturated fats are omega-3 and omega-6 fatty acids.

Properties of Lipids

General characters of lipids are:

1. Lipids are relatively insoluble in water.
2. They are soluble in non-polar organic solvents, like ether, chloroform, and methanol.
3. Lipids have high energy content and are metabolized to release calories.
4. Lipids also act as electrical insulators. They insulate nerve axons.
5. Fats contain saturated fatty acids. They are solid at room temperatures. Example, animal fats.
6. Plant fats are unsaturated and are liquid at room temperatures.
7. The melting point of fats depends on the length of the chain of the constituent fatty acid and the degree of unsaturation.

Functions of Lipids

Lipids perform several biological functions:

1. Lipids are storage compounds, triglycerides serve as reserve energy of the body.
2. Lipids are important component of cell membranes structure in eukaryotic cells.
3. Lipids regulate membrane permeability.
4. They serve as source for fat soluble vitamins like A, D, E, and K.
5. They act as electrical insulators to the nerve fibres, where the myelin sheath contains lipids.
6. Lipids are components of some enzyme systems.
7. Some lipids like prostaglandins and steroid hormones act as cellular metabolic regulators.
8. Layers of fat in the subcutaneous layer, provides insulation and protection from cold.
9. Body temperature maintenance is done by brown fat.
10. They protect may vital organs like heart and kidney.

CHOLESTEROL

Cholesterol is a waxy substance that comes from two sources: human body and food. Our body, and especially liver, makes all the cholesterol needed and circulates it through the blood. But cholesterol is also found in foods from animal sources, such as meat, poultry and full-fat dairy products. Liver produces more cholesterol when we eat a diet high in saturated and Trans-fats. Excess cholesterol can form plaque between layers of artery walls, making it harder for your heart to circulate blood. Plaque can break open and cause blood clots. If a clot blocks an artery that feeds the brain, it causes a **stroke.** If it blocks an artery that feeds the heart, it causes a **heart attack**. It may surprise you to know that cholesterol itself isn't bad. In fact, cholesterol is just one of the many substances created and used by our bodies to keep us healthy.

Types of cholesterol

There are two types of cholesterol: "good" and "bad." Too much of one type — or not enough of another — can put you at risk for coronary heart disease, heart attack or stroke. Cholesterol can't dissolve in the blood. It must be transported through your bloodstream by carriers called lipoproteins, which got their name because they're made of fat (lipid) and proteins. The two types of lipoproteins that carry cholesterol to and from cells are low-density lipoprotein, or LDL, and high-density lipoprotein, or HDL. LDL cholesterol and HDL cholesterol, along with one fifth of your triglyceride level, make up your total cholesterol count, which can be determined through a blood test.

LDL (Bad) Cholesterol

LDL cholesterol is considered the "bad" cholesterol because it contributes to plaque, a thick, hard deposit that can clog arteries and make them less flexible. This condition is known as atherosclerosis. If a clot forms and blocks a narrowed artery, heart attack or stroke can result. Another condition called peripheral artery disease can develop when plaque build-up narrows an artery supplying blood to the legs.

HDL (Good) Cholesterol

HDL cholesterol is considered "good" cholesterol because it helps remove LDL cholesterol from the arteries. Experts believe HDL acts as a scavenger, carrying LDL cholesterol away from the arteries and back to the liver, where it is broken down and passed from the body. One-fourth to one-third of blood cholesterol is carried by HDL. A healthy level of HDL cholesterol may also protect against heart attack and stroke, while low levels of HDL cholesterol have been shown to increase the risk of heart disease.

High levels of triglycerides in the blood are associated with atherosclerosis. Elevated triglycerides can be caused by overweight and obesity, physical inactivity, cigarette smoking, excess alcohol consumption and a diet very high in carbohydrates (more than 60 percent of total calories). Underlying diseases or genetic disorders are sometimes the cause of high triglycerides. People with high triglycerides often have a high total cholesterol level, including a high LDL cholesterol (bad) level and a low HDL cholesterol (good) level. Many people with heart disease or diabetes also have high triglyceride levels.

VITAMINS AND MINERALS

Both vitamins and minerals are needed by the body in very small amounts to trigger the thousands of chemical reactions necessary to maintain good health. Many of these chemical reactions are linked, with one triggering another. If there is a missing or deficient vitamin or mineral anywhere in this chain, this process may break down, with potentially devastating health effects.

- The most prominent function of the vitamins and minerals is that they act as cofactor.

- Along with their many functions, they enhance the body's use of carbohydrates, proteins, and fats.
- They are critical in the formation of blood cells, hormones, nervous system chemicals known as neurotransmitters, and the genetic material deoxyribonucleic acid (DNA).

One misconception about vitamins and minerals is that they provide energy to the body. Vitamins and minerals don't provide even a single calorie rather they regulate the metabolism hence ensure the supply of energy to the body.

"Vitamin is any of the organic compounds that the body requires in small amounts to maintain health and function properly."

The Rhythm Nearly Proved Purely Contagious

Mnemonic device to remember water soluble vitamins. In this, "T" for **Thiamine,** R is **Riboflavin,** N is **Niacin,** P is **Pantothenic acid,** P is **Pyridoxine** and C is **Cobalamin.**

Vitamins are classified into two groups: fat soluble and water soluble.

Fat-soluble vitamins include vitamins A, D, E, and K, which are usually absorbed with the help of foods that contain fat. Fat containing these vitamins is broken down by bile, a liquid released by the liver, and the body then absorbs the breakdown products and vitamins. Excess amounts of fat-soluble vitamins are stored in the body's fat, liver and kidneys. Because these vitamins can be stored in the body, they do not need to be consumed every day to meet the body's needs.

Water-soluble vitamins include vitamin C (also known as ascorbic acid) and vitamin B complex. Vitamin B is composed of eight vitamins, but they are grouped together as vitamin B complex. The B-complex vitamins are B1 (Thiamine), B2 (Riboflavin), B3 (Niacin), B5 (Pantothenic acid), B6 (Pyridoxine), B7 (Biotin), B9 (Folic acid) and B12 (Cyanocobalamin). These cannot be stored and rapidly leave the body in urine if taken in greater quantities than the body can use. Foods that contain water-soluble vitamins need to be eaten daily to replenish the body's needs. Following table enlists various vitamins, their sources health benefits and effects of their deficiency or excess in the body.

Vitamins Table

Fat-soluble	**Sources**	**Health Benefit**	**Deficiency & Excess Effects**
A (Retinol)	Green vegetables, milk and its products, liver, eggs and carrots	Component of light-sensitive pigments in eye, epithelial tissue maintenance	Night blindness, permanent blindness. High dosage can be toxic and can lead to bone fractures and birth defects.
D (D1 & D3)	Dairy products, eggs, cod liver oil and steroid containing foods irradiated with ultraviolet light.	Calcium absorption and bone formation	Rickets (bone deformities) Osteomalacia (softening of bones) High dose causes excessive calcium deposits and mental retardation.
E (Tocopherol)	Margarine, seeds, green leafy vegetables, nuts	Antioxidant	Sterility, anaemia and damages to the retina. High dosage may be toxic.

K (Manadion)	Green leafy vegetables and synthesized by intestinal bacteria	Blood clotting	Uncontrolled bleeding. High dosage may be toxic especially in infants.
Water-Soluble			
B1 (Thiamine)	Organ meats, grains, legumes and yeast.	Carbohydrate metabolism, nerve and heart function, act as coenzyme	Beriberi (weakened heart, nerve and muscle degeneration, pain and swelling).
B2 (Riboflavin)	Milk and dairy products, liver, eggs, grains, legumes and cheese	Used in cellular respiration	Eye irritation, inflammation and breakdown of skin cells.
B3 (Niacin or Nicotinic Acid)	Liver, lean meats, grains, legumes and yeast.	Oxidation-reduction reactions in cellular respiration	Pellagra (The 3 D's of pellagra: Dermatitis, Diarrhoea and Dementia)
B5 (Pantothenic Acid)	Milk products, liver, eggs, grains, legumes	Energy metabolism	Fatigue, loss of coordination.
B6 (Pyridoxine)	Whole-grain cereals, vegetables, meats	Amino acid metabolism	Convulsions, irritability, kidney stones.
B7 (Biotin)	Meats, vegetables, legumes	Fat synthesis and amino acid metabolism. Cofactor	Depression, fatigue, nausea.
B12 (Cobalamin)	Red meats, eggs, dairy products	Nucleic acid production especially DNA	Pernicious anaemia, neurological disorders.
C (Ascorbic Acid)	Citrus fruits, green leafy vegetables, tomatoes	Collagen formation in teeth, bone and connective tissue of blood vessels. Antioxidant	Scurvy (breakdown of skin, blood vessels and teeth).
B9 (Folic Acid)	Whole-wheat foods, green vegetables, legumes	Nucleic acid metabolism	Anaemia, birth defects. Very important for pregnant women.

DIETARY MINERALS

Mineral nutrients are classified as *major elements* (calcium, chlorine, magnesium, phosphorus, potassium, sodium, and sulphur) and *trace elements* (copper, fluoride, iodine, iron, selenium and zinc). Major elements are required in larger quantities and micronutrients or trace elements are required to the body in very small amounts.

Minerals	Role in Body	Deficiency symptoms
Calcium	Bone and teeth formation, blood clotting, and nerve transmission	Rickets, osteoporosis, convulsions
Chlorine	Fluid regulation between cells or cell layers. Nerve transmission	Acid-base imbalance in body fluids (very rare)
Magnesium	Enzyme activation, protein synthesis. (also part of chlorophyll molecule)	Growth failure, behaviour problems, spasms
Phosphorus	Bone and teeth formation, acid-base balance maintenance	Weakness, loss of calcium
Potassium	Acid-base balance and fluid balance maintenance, nerve transmission	Muscle cramps, mental confusion, loss of appetite, irregular cardiac rhythm
Sulphur	Acid-base balance maintenance and liver function	Disorders unlikely if body gets small amounts needed
Sodium	Acid-base balance and body water balance maintenance, nerve function	Muscle cramps, reduced appetite, mental apathy
Copper	Red blood cells formation	Anaemia, impairs bone and nervous tissue development
Fluorine	Bone structure maintenance, decay-resistant teeth	Osteoporosis; tooth decay
Iodine	Component of thyroid hormone	Enlarged thyroid (goitre)
Iron	Haemoglobin formation in blood and energy metabolism	Anaemia
Selenium	Prevents breakdown of fats and other body chemicals	Anaemia
Zinc	Component of many enzymes included in digestion, cell repair, sexual reproduction	Growth failure, small sex glands, delayed wound healing

ENZYMES

"Enzyme is specialized organic substance, composed of polymers of amino acids that act as catalysts to regulate the speed of the many chemical reactions involved in the metabolism of living organisms." There are various types of enzymes and each one is responsible for a particular chemical reaction only. While, most enzymes are associated with metabolic processes, like, digestion and breathing, there are some, which are related to blood clotting, healing of wounds, controlling the production of hormones, destroying pathogens and environmental toxins, etc. Individual enzymes are named by adding *ase* to the name of the substrate (the substance acted upon by an enzyme) with which they react. For example, the enzyme that controls urea decomposition is called *urease*. Some enzymes, such as *trypsin* and *pepsin*, retain the names used before this nomenclature was adopted.

Structure of Enzyme

Enzymes are highly selective, they catalyse specific reactions only. Enzymes have a part where only certain kind of substrate can bind to it, this site of activity is known as the *'active site'*. The molecules that react and bind to the enzyme is known as the *'substrate'*.

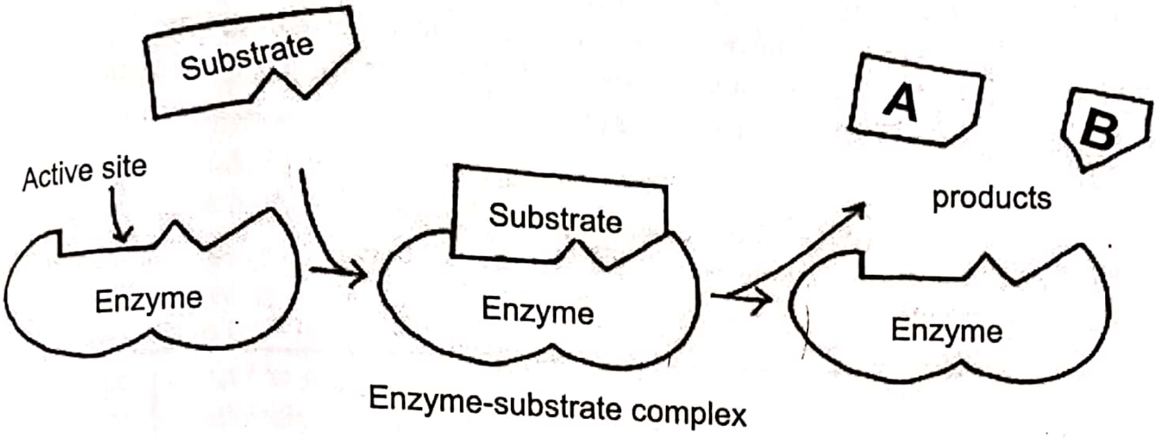


Figure : Enzyme Structure & Key Lock Model

Most of the enzymes consists of the protein and the non protein part is called the '*cofactor*'. The proteins in the enzymes are usually globular proteins. The protein part of the enzymes are known '*apoenzyme*'. Together the apoenzyme and cofactors are known as the '*holoenzyme*'.

Enzyme's Characteristics

1. The basic function of an enzyme is to increase the rate of a reaction. Most cellular reactions occur about a million times faster than they would in the absence of an enzyme.
2. All enzymes are proteinous in nature.
3. Most enzymes act specifically with only one substrate to produce products. For example, pepsin would only act on proteins.
4. Most remarkable characteristic is that enzymes are regulated from a state of low activity to high activity and vice versa.
5. Enzymes are site specific; they work like a *key and lock* and it is called key lock model. It means enzymes would only attach on a specific site of the substrate.
6. Enzymes are highly sensitive to pH and temperature changes.

Functions of Enzymes

Enzymes perform a wide variety of functions in living organisms. They are major components in signal transduction and cell regulation, kinases and phosphatases help in this function. They take part in bodily movement with the help of the protein myosin which aids in muscle contraction. Enzymes play an important role in the digestive activity. Enzymes breakdown large molecules into absorbable molecules. Variuos enzymes work together in an order forming metabolic pathways, for example glycolysis.

Application of Enzymes

Food Processing - Amylases enzymes are used in production of sugars from starch in making corn-syrup. *Catalyze enzyme* is used in breakdown of starch into sugar, and in baking fermentation process of yeast raises the dough. *Proteases enzyme* help in manufacture of biscuits and in lowering the protein level. *Baby foods* - Trypsin enzyme is used in pre-digestion of baby foods. *Brewing industry* - Enzymes from barley are widely used in brewing industries. Amylases, glucanases, proteases, betaglucanases, arabinoxylases, amyloglucosidase, acetolactatedecarboxylases are used in prodcution of beer industries. *Fruit juices* - Enzymes like cellulases, pectinases are used